Yazoo River

SEDIMENTATION STUDY OF THE YAZOO RIVER BASIN

PHASE I TEMPORAL DESIGN

CONTRACT NO. DACW 38-76-C-0193

Prepared for

U. S. ARMY CORPS OF ENGINEERS
VICKSBURG DISTRICT
Vicksburg, Mississippi

CSU 1870

Prepared by

Civil Engineering Department
Engineering Research Center
Colorado State University
Fort Collins, Colorado

D. B. Simons
R. M. Li
T. J. Ward
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AUTHORIZATION

This investigation was conducted for the U.S. Army Corps of Engineers, Vicksburg District, Lower Mississippi Division under Contract No. DACW38-76-C-0193. Larry Banks and Larry Eckenrod were the authorized Project Managers for the Vicksburg District and Daryl B. Simons and Ruh-Ming Li were the Principal Investigators for Colorado State University. The purpose of this investigation is to determine the extent of sediment problems in the main stem Yazoo-Tallahatchie-Coldwater River System and principal tributaries excluding the Sunflower River Basin. In addition, this study recommends ways to control these sedimentation problems and others that may be encountered with the proposed Upper Auxiliary Channel Alternative Project in operation. This report details techniques for developing discharge records for the Yazoo River Basin Sedimentation Study.

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I. INTRODUCTION

An accurate set of discharge records is necessary for modeling a river system. These records should be developed for key river system locations during a consistent time span. Before development can be initiated, a thorough review of existing records followed by the delineation of realistic spatial and temporal frameworks must be completed. Data review indicates what types of discharge information are available at specific locations. This information may include daily discharge, instantaneous stage readings, peak discharge or intermittent measurements. Once data availability and adequacy is ascertained, spatial and temporal designs can be formulated. An order of magnitude analysis of potential sediment contributions, the available gaging stations and conferring with knowledgeable field personnel leads to a spatial design that includes important river and tributary sites. These sites are determined, in part, by the discharge of water and sediment past the site, and the overall stability of the channel reach surrounding the site. Data availability is then used to determine the method of record development for each site. At some sites, an adequate set of discharge or stage records exists, however, at other sites no data exists. If the site is relatively unimportant, it may be excluded from further consideration. If it is important, a record must be synthesized for that site.

The time span of records or temporal resolution is also important in modeling. This temporal design is again determined by the availability and duration of records at each site. Some sites may have continuous records covering a long period of time while others may have only intermittent records for a few years. Records are compared until a common time span is found allowing selection of the temporal design.

For the Yazoo River Basin Sedimentation study, both spatial and temporal designs were determined after analysis of existing data. The spatial design is shown in Appendix A, divided into upper and lower river reaches. The current spatial design of 62 sites includes 30 sites with existing stage or discharge records, 14 ungaged sites, and 18 disperse or non-point sources. The period of record chosen was from January 1, 1964 to December 31, 1974. This 11-year period was used because of data availability for discharge or stage records at the 30 gaged sites. Flows at each site were constrained to average daily discharges. However, close proximity of the sites made water travel times between adjacent sites one day or less under most flow conditions. A total of 4,018 average daily flow values for the 11-year period formed the basic data set for extension and synthesis.

One set of records developed from the 11-year data set was 574 average weekly flow values, i.e., the average daily flow for a seven day period. These 574 values were in turn used to generate an extended record of an additional 39 years for all sites, a total of 2,609 values for 50 years. This extension was conducted using statistical techniques with checks to assure generation of realistic values. The sequence used for developing sets of 11 years of daily and 50 years of weekly discharge values is shown in Figure 1. Each element in the sequence is checked to avoid unrealistic values or other errors. Development of daily and weekly discharge records are detailed in this report. Techniques and typical examples are presented to clarify the approach used.

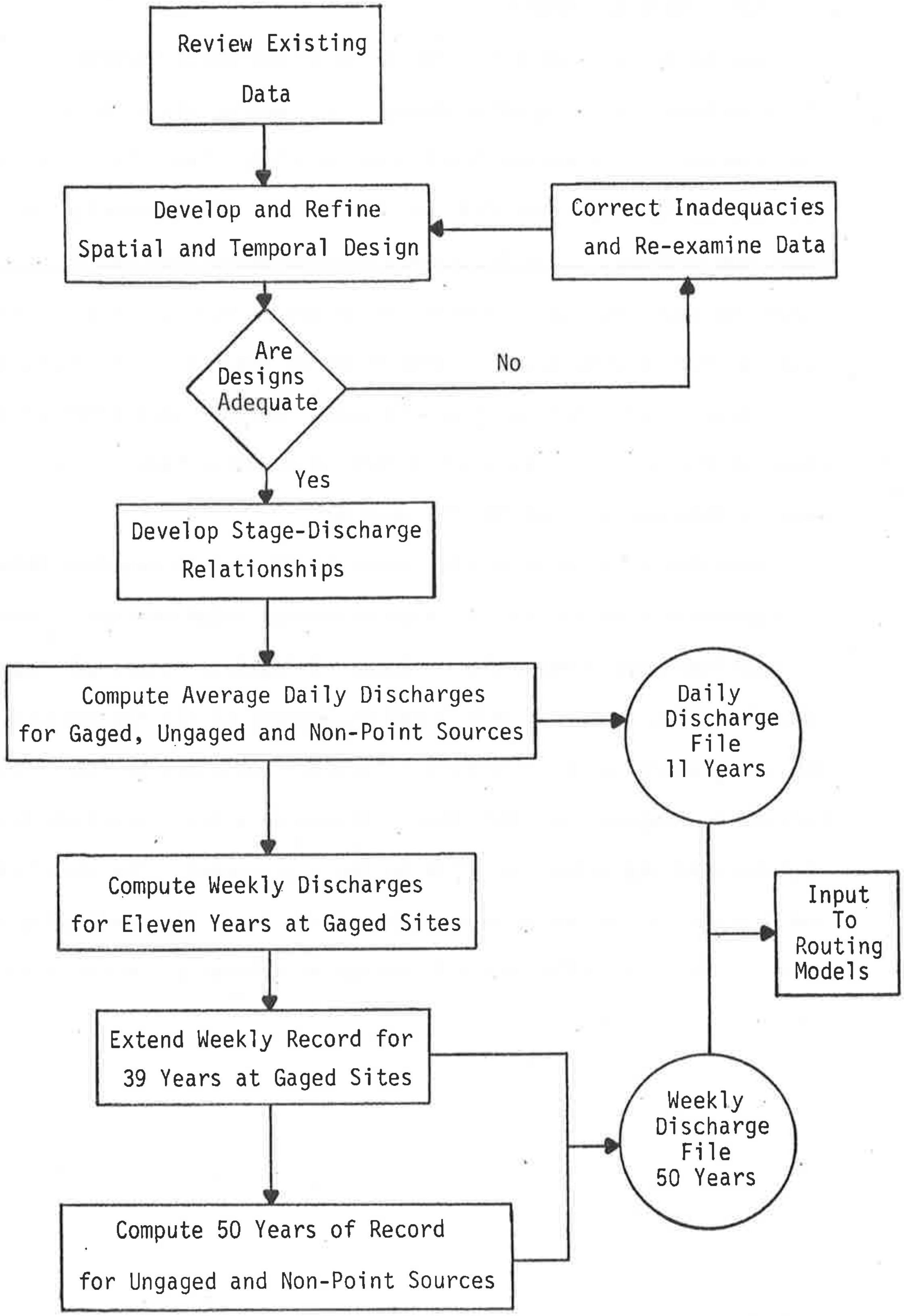

Figure 1. Sequence of discharge record development.

II. DATA NEEDS AND SOURCES

The basic need was for a set of daily discharge records at all sites included in the spatial design. For seven sites, Coldwater River near Lambert, Tallahatchie River near Swan Lake, Yazoo River at Greenwood and outflows for the four major reservoirs of Arkabutla, Sardis, Enid, and Grenada, daily discharges were obtained from the U.S. Geological Survey on magnetic tapes. These discharges were computed from stage readings supplied by the U.S. Army Corps of Engineers, Vicksburg District.

Stage records for the other 23 gaged stations were supplied by the Corps of Engineers, Vicksburg District on magnetic tape. Stage readings were at 0800 hours (8:00 AM) for each day.

Computer conversion of the stages to discharges required development of mathematic expressions for stage-discharge relationships. Some formulations were developed from Corps of Engineers observed stage and discharge data found in "Stages and Discharges of the Mississippi River and Tributaries in the Vicksburg District," published by the Corps of Engineers. Expressions for other stations were developed from Corps of Engineers rating curves supplied by their personnel. The observed stages and discharges and rating curves formed the basis for developing mathematical expressions for stage-discharge relationships on the Yazoo River and its tributaries.

III. DEVELOPMENT OF AVERAGE DAILY DISCHARGES

3.1 Stage-Discharge Relationships

The stage-discharge data available for Yazoo River gaging stations can be adequately related by a power equation of the form

$$Q = a(S + c)^b \qquad (1)$$

or by a linear equation of the form

$$Q = mS + k \qquad (2)$$

where Q is the discharge, S is the stage, C is a value used to transform the stage readings, and a, b, k and m are empirical values. The parameter c is used to force the power function through a point of zero discharge at relative zero stage height. The power function, Equation 1, was used to define the stage-discharge relationships at most stations. If overbank flow occurred at the gaging section, then a linear function in the form of Equation 2 best fit the overbank data, while the power function best fit the in-bank data. An example of the power function fit is shown in Figure 2 for the Coldwater River near Crenshaw. Figure 3 shows a combined power function and linear function stage-discharge relationship for the Yalobusha River at Whaley. Although bank full stage is about 21 feet, data indicates that a match point between the two functions may be nearer to 25 feet. Therefore, stages above 25 feet were used in computing the linear function and stages less than 25 feet were used for the power function. The two functions coincide at a stage of 25.34 feet. Above this stage the linear function was used, below this stage the power function was used. A complete set of stage-discharge relationship parameters is presented in Appendix B.

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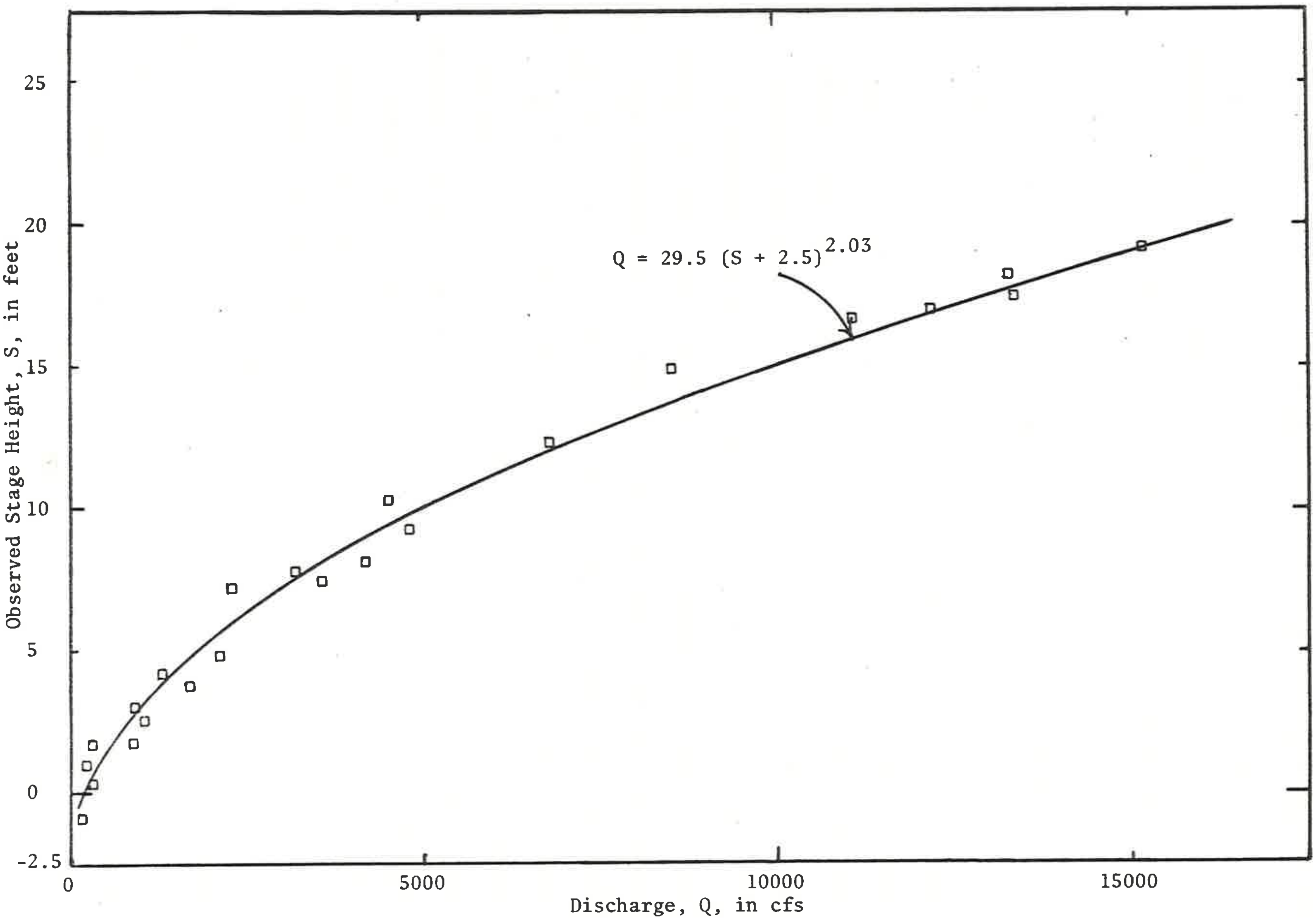


Figure 2. Power function fit of the stage-discharge relationship for the Coldwater River near Crenshaw.

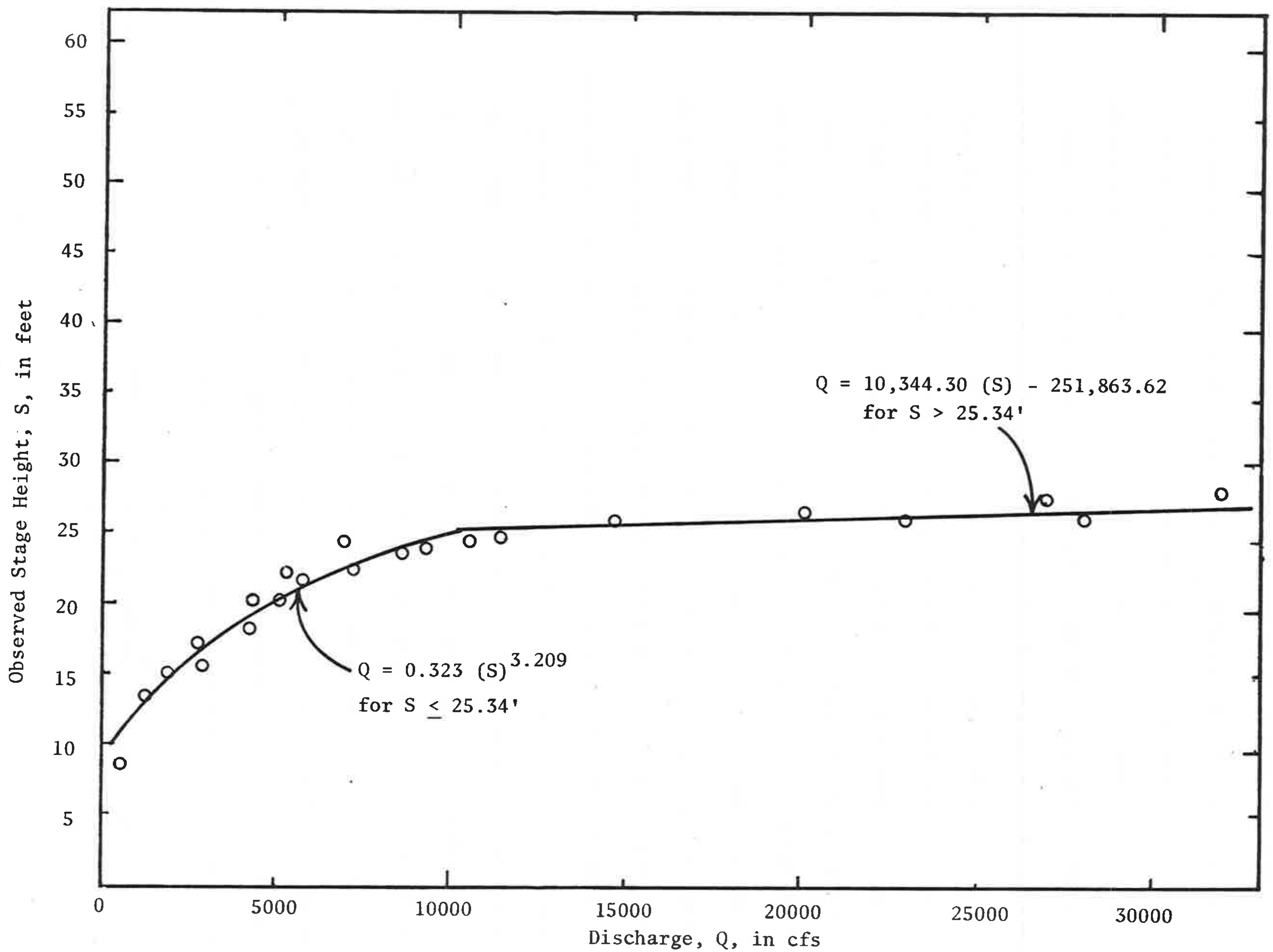


Figure 3. Power and linear function fits of the stage-discharge relationship for the Yalobusha River at Whaley.

Six stations required particular attention when discharges were computed. The first two stations where the computed stage-discharge relationship needed to be altered were the one at Coldwater River near Prichard and the one near Marks. It was noted the original relationship for these stations produced discharges that yielded a relatively low average discharge over the 11-year base period. These average discharges were in fact less than the average discharge of the next upstream gaged site. It was also noted that the gain in average discharge between two sites was about one cfs per square mile. This observation was used to adjust the stage-discharge relationships at both stations to coincide with changes in average discharge observed elsewhere between the sites. Adjustment for the Marks relationship was facilitated by obtaining a Corps of Engineers rating curve for this site. Although different from the relationship computed from available data, the rating curve did provide the desired results. For Prichard, the parameter b in Equation 1 was increased slightly to produce the desired results. This increase had the effect of generating a higher estimated discharge at the same stage as compared to the original relationship. The adopted relationships for these two stations provided discharges consistent with other river sites.

A problem in converting stages to discharges was that of missing stage readings. Generally, only a few readings were missing from any particular site. In such cases, linear interpolation was used to estimate the discharges between two computed values as

$$\hat{Q}_i = Q_{last} + \left[\frac{Q_{next} - Q_{last}}{t_{next} - t_{last}}\right] [t_i - t_{last}] \tag{3}$$

where $\hat{Q}_i$ is the interpolated value, Q_{last} is the last computed 8:00 AM discharge before the missing record, Q_{next} is the next computed discharge after the missing record, and t_i, t_{last}, and t_{next} are the corresponding times in days from beginning of record for these discharges. This scheme works well for short breaks in the record on a slightly fluctuating stream. One problem site, Arkabutla Canal (Creek) southwest of Arkabutla, did not meet these criteria. Discharge in Arkabutla Canal can fluctuate highly during a single day. This fluctuation, combined with missing records of four days or more duration, produced some odd interpolated values. Of particular concern were four consecutive days in March of 1965 that had extremely high 8:00 AM stage readings for the last and next values. Linear interpolation produced a set of high discharges that were unmatched in any previous or subsequent set of records. These high values were discovered upon inspection of the record and a different approach for interpreting the missing values was used. For this site, stages were related to the stages at Coldwater River near Sarah. Although lower, the resulting discharges were still higher than what is considered realistic. Manual adjustment of the discharges was finally used to correct these abnormally large values.

Extension of records was also needed for Tchula Lake Cut-off near Mileston. Stages at this site have been collected since April 15, 1969, but data was needed from January 1, 1964. Records were estimated by relating the existing stages at Mileston to stages of the Yazoo River at Belzoni. Both linear and power functions were used to define the relationship with the linear form providing the best correlation. This relationship was

$$S_{Mileston} = 18.74 + 0.2936\ S_{Belzoni} \qquad (4)$$

where $S_{Mileston}$ is the 8:00 AM stage at Mileston and $S_{Belzoni}$ is the corresponding 8:00 AM stage at Belzoni. This relationship was used to estimate the missing stages. Some other sites also required use of nearby stage readings.

The final two sites that required particular attention were the Yazoo River Overflow near Marksville and the Lower Auxiliary Channel Overflow near Silver City. Overflow at the Marksville site was related to the stage at Belzoni while overflow from the Yazoo River into the Lower Auxiliary Channel (LAC) is related to the Silver City stage readings.

In addition to these six specific sites, there were other problems with the stage records supplied by the Corps of Engineers. A major problem was encoding errors, particularly for 1973, where symbols were inconsistent with other years and additional keypunch errors were found. Fortunately, these errors were easily detected and corrected. The conversion of stages to discharges was conducted after stage data was edited and corrected. This conversion created a set of 8:00 AM discharges that were then changed to daily flow values.

3.2 Computation of Daily Flow Values

Because only 8:00 AM discharges were available, an interpolation scheme was needed to define the hydrograph during the 12 midnight to 12 midnight period of the day in question. The scheme utilized here interpolated the discharge for the previous and post 12 midnight times relative to the 8:00 AM discharge and then averaged these two values. Special attention was given to the first and last days. Computation of daily discharge for all days was of the form

$$\overline{Q}_i = \frac{Q_{Pi} + Q_{Ni}}{2} \qquad (5)$$

where $\overline{Q}_i$ is the average daily flow for day i, Q_{Pi} is the previous 12 midnight discharge and Q_{Ni} is the subsequent or next 12 midnight discharge. For days 2 through 4017, Q_P and Q_N were computed as

$$Q_{Pi} = Q_i - \frac{(Q_i - Q_{i-1})}{3} \tag{6}$$

and

$$Q_{Ni} = Q_i + \frac{2}{3} (Q_{i+1} - Q_i) \tag{7}$$

where Q_{i-1}, Q_i, and Q_{i+1} are 8:00 AM discharges before, during and after day i, respectively. First and last day values required extrapolation formulations. For first day values these were:

$$Q_{P1} = Q_1 - \frac{(Q_2 - Q_1)}{3} \tag{8}$$

and

$$Q_{N1} = Q_1 + \frac{2}{3} (Q_2 - Q_1) \tag{9}$$

Similarly, for last day values

$$Q_{P4018} = Q_{4018} - \frac{(Q_{4018} - Q_{4017})}{3} \tag{10}$$

and

$$Q_{N4018} = Q_{4018} + \frac{2}{3} (Q_{4018} - Q_{4017}) \tag{11}$$

Statistics for the daily discharges formed by Equation 5 were also computed. These statistics included maximum, minimum, average and standard deviation. A listing of these statistics is presented in Appendix C. The computer program used to convert stages to discharges, interpolate missing discharges, compute daily flow and calculate flow statistics is presented in Appendix D. Development of daily discharge records for gaged sites allowed creation of weekly flow records for gaged sites and computation of daily and weekly flow values for ungaged and non-point sources.

IV. DEVELOPMENT AND GENERATION OF WEEKLY DISCHARGES

Weekly discharges were found by computing the average daily discharge for seven day periods. For example, days 1 through 7 would have a single average daily discharge and days 8 through 14 another. A seven day period was chosen since it represented average time necessary for water to travel from Arkabutla Dam to Vicksburg. Seven days also produced exactly 574 time steps from the original 11 years of daily discharges. Because the sedimentation model for the main stem Yazoo River is to be operated as a predictive or management aid, realistic long term records beyond the original 574 values were required. This necessitated extension of the 11-year discharge base to 50 years, an addition of 39 years or 2035 weekly average discharges. Extension was conducted using current time series analysis techniques that preserve the mean, variance and autocorrelation structure of the historical 11-year discharge base.

Time series models are often fitted to the autocorrelation function or equivalently its Fourier transform. The stationary component of the time series is then removed. Research has shown the best method is to synthesize logarithms of the flows using an Auto-Regressive Moving Average Scheme (ARMA) with time varying auto-regressive (AR) coefficients that preserve long range dependence of the hydrologic series. The approach used here employed Kalman filtering to improve fitting of an AR (2) (auto-regressive lagged two-time periods) model to the historic data. This model was then used to extend the 11-year record.

The first step in analysis of a hydrologic time-series is the removal of the nonstationarity or periodicities in the mean and variance of the observed data. For that purpose, the <u>fitted standardization method</u>

was used. In this approach, hydrologic processes are assumed to be composed of a deterministic periodic component and a stochastic residual component. With the periodic mean μ_t and the periodic standard deviation σ_t, the model for the hydrologic process (discharge) $Q_{p,t}$ is

$$Q_{p,t} = \mu_t + \sigma_t \, y_{p,t} \tag{12}$$

where p represents a specific year, t is a time period in that year (such as a weekly value or 52 weeks per year) and $y_{p,t}$ is the stochastic component which is stationary at least for the mean and the variance. The parameters μ_t and σ_t in Equation 12 were estimated by the harmonic models

$$\mu_t = m_x + \sum_{i=1}^{6} (A_i \cos \frac{2\pi it}{\omega} + B_i \sin \frac{2\pi it}{\omega}) \tag{13}$$

$$\sigma_t = S_x + \sum_{i=1}^{6} (A_i \cos \frac{2\pi it}{\omega} + B_i \sin \frac{2\pi it}{\omega}) \tag{14}$$

where m_x and S_x are the averages of the sample mean Q_t and the sample standard deviation S_t of $Q_{p,t}$ at time period t and ω is the basic cycle for the time series (52 for this application), and A_i and B_i are Fourier coefficients. The sample mean Q_t is found from

$$Q_t = \frac{1}{n} \sum_{p=1}^{n} Q_{p,t} \tag{15}$$

and the sample standard deviation is

$$S_t = [\frac{1}{n-1} \sum_{p=1}^{n} (Q_{p,t} - Q_t)^2]^{1/2} \tag{16}$$

where n is 11 years. Therefore, for each weekly time period, one to 52, a mean value and standard deviation was computed. The averages of these two statistics were then used in Equations 13 and 14. The Fourier coefficients A_i and B_i for this sixth order harmonic (i=1, ...6) were estimated by a least-squares technique. After completing the standardization process described above, the resulting stationary time-series was fitted to an AR (2) model of the form

$$y_{p,t} = a_{t_1} y_{p,t-1} + a_{t_2} y_{p,t-2} \tag{17}$$

where a_{t_1} and a_{t_2} are the AR coefficients at time period t, and $y_{p,t-1}$ and $y_{p,t-2}$ are the stochastic components for year p at one and two previous time periods, respectively. A Kalman filtering technique was used for this purpose because of its ability to track the variations of the AR-coefficients with time and under noisy (fluctuating) observed data, which is the case for water discharge.

A sixth order harmonic polynomial of the form

$$a_{t_2} = \sum_{i=1}^{6} (K_{1_i} \cos \frac{2\pi it}{\omega} + K_{2_i} \frac{\sin 2\pi it}{\omega}) \tag{18}$$

where K_{1_i} and K_{2_i} are the Fourier coefficients and ω is again 52 (see Equation 13 or 14) was then used to extend the AR-coefficients forward in time to obtain a complete time-varying model for the standardized logarithm of the discharge time-series. After the complete time varying model was constructed, predicted, and observed discharge values were compared. The differences between predicted and observed values, residuals, were used to generate random errors, i.e., noise in the time series. Essential to this generation were the mean, standard deviation and lag-1 autocorrelation of the residuals. These residuals were assumed to be normally distributed allowing standard random number generation techniques to be used in their estimation.

The above procedures for determining the discharge time-series can be summarized as:

1) Compute the average discharge for each seven day period
2) Take the logarithm of the average discharge data
3) Eliminate the nonstationarity in the data by the fitted standardization method
4) Fit an AR (2) model to the standardized time-series by Kalman filtering
5) Fit a 6th order harmonic model to the coefficients of the AR (2) model
6) Calculate the statistics (i.e., mean, standard deviation and lag-1 autocorrelation coefficient) of the residuals for the complete time-varying model. These statistics will be used to generate random noise which will be added to the generated data from the time-varying AR (2) model when synthesized data is desired.

Synthesized streamflow data was then obtained through the following inverse operations:

1) Generate normally distributed random numbers based on the statistics of the residuals of the model.
2) Generate the values for the coefficients of the AR (2) model based on the 6th order harmonic models.
3) Generate the standardized time-series with the AR (2) model including normally distributed random noise which was generated in step (1).

4) De-standardize the data to return to the logarithm of streamflow time-series based on Equation 12.

5) Take the exponential of the generated data.

6) Check lower and upper bounds on the generated values.

7) Check the simulated flow characteristics with the historical flow characteristics, such as frequency of occurrence of peak flow and flow volume distribution.

If the flows were realistic and consistent, the flow series was accepted for further use. Computer programs for computing a weekly time-series are presented in Appendix D.

4.1 Results of Development

A summary of daily and weekly flow values used in this study are listed in Appendix 2. As this appendix shows, the simulated record retained the characteristics of the observed record particularly for the gaged stations.

This similarity can be seen by comparing Figures 4 and 5. Figure 4 shows 574 observed historic flows for Tallahatchie (Coldwater) River near Lambert and Figure 5 shows the next 574 flows as generated by a time-series model. As these figures indicate, the time-series model retained the cyclical nature and relative magnitudes of the actual data. Similar plots for fifty years of actual and simulated records are presented in Appendix E. Completion of discharge extension allowed computation of ungaged and non-point source inputs; these computations being the final step in discharge record development.

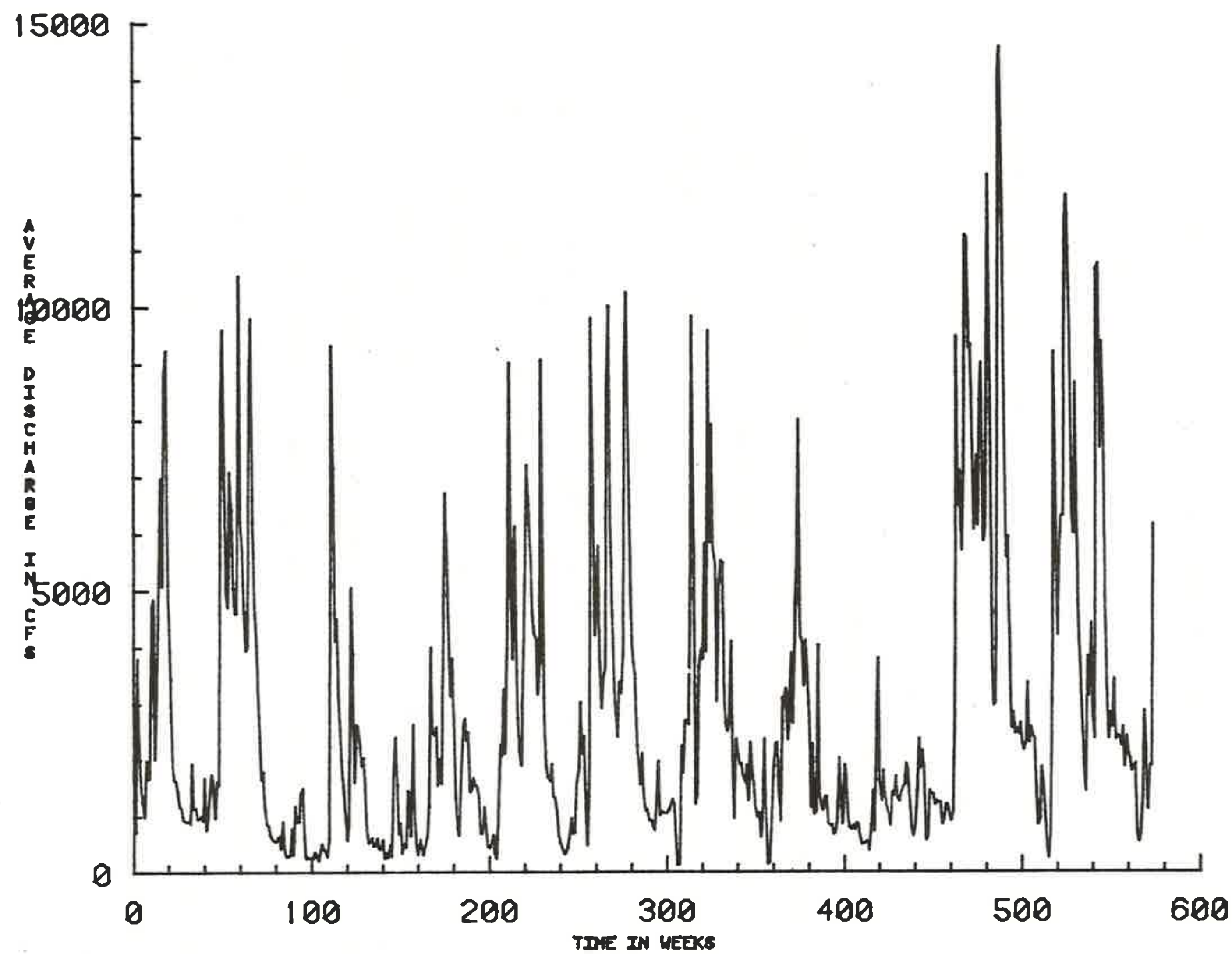


Figure 4. Seven-day average discharge for Tallahatchie River near Lambert, observed discharges.

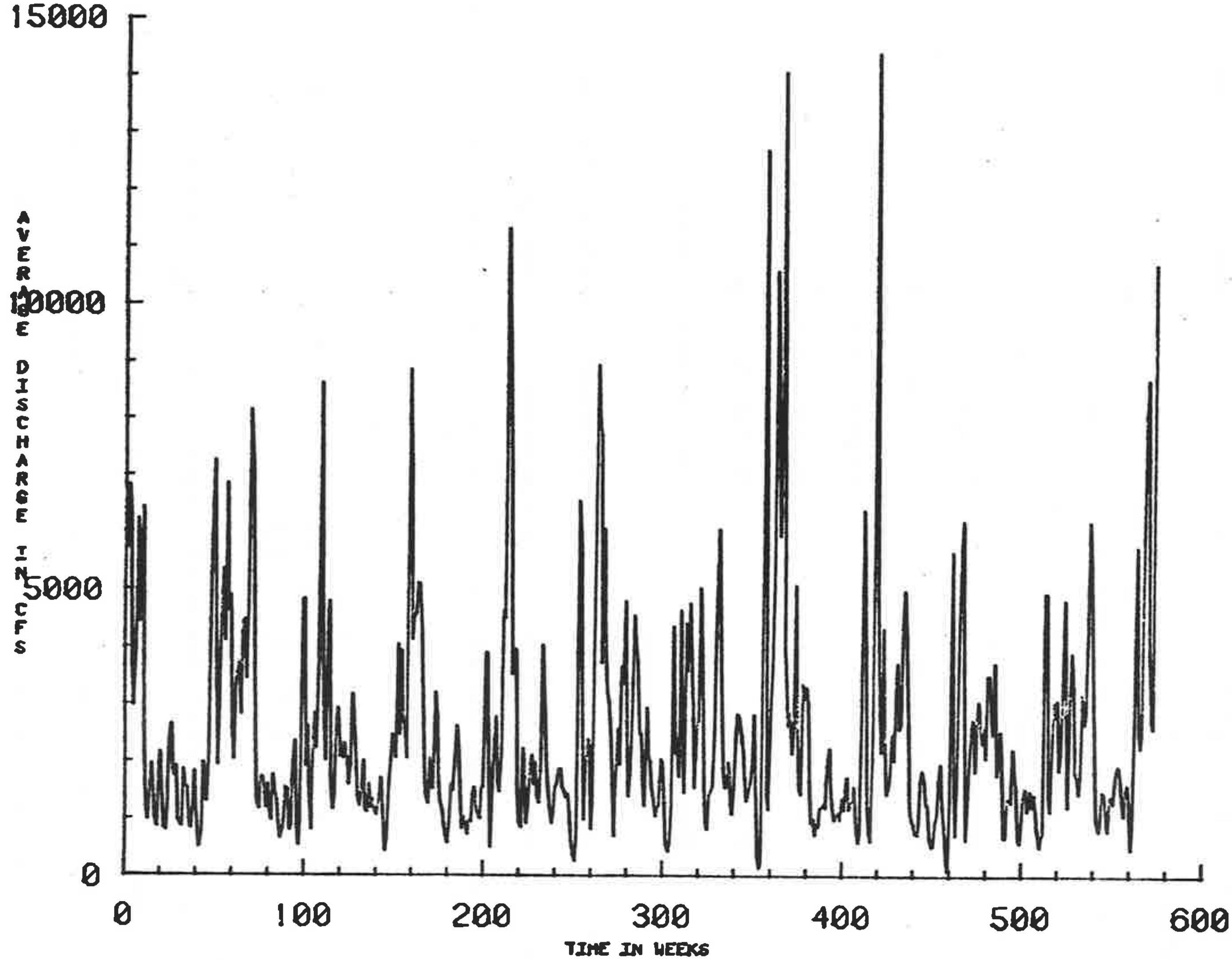


Figure 5. Seven-day average discharge for Tallahatchie River near Lambert, generated discharges.

V. UNGAGED AND NON-POINT SOURCE RECORDS

5.1 Ungaged Sources

An ungaged source is an important watershed of definable area that lacks continuous stage or discharge data. Ungaged sources are listed in Table 1.

Table 1. Ungaged Sources for the Yazoo River Basin Study

Short Creek	Cane Creek
Piney Creek	Batupan Bogue
Tescheva Creek	Tillatoba Creek
Black Creek	Peters Creek
Fannegusha Creek	McIvor Drainage
Teoc Creek	Strayhorn Creek
Potococowa Creek	Lake Cormorant Bayou

These fourteen sources were computed using flow records from nearby stations. Two types of relationships were used. If nearby, similar gaged sites existed, the discharge value for the ungaged site was computed as

$$Q_{UG} = \frac{A_{UG}}{n} \left(\sum_{J=1}^{n} \left(\frac{Q_G^J}{A_G^J} \right) \right) \tag{19}$$

where Q_{UG} is the discharge at the ungaged site, A_{UG} is area of the ungaged watershed contributing to the site, Q_G^J is the discharge at gaged site J, A_G^J is watershed area contributing to gaged site J, and n is the number of sites used. Nine of the 14 ungaged sources were computed using Equation 19. Discharges for Short, Piney, Tescheva, Black and Fannegusha Creeks were computed using data from Pelucia and Abiaca Creeks. Teoc, Potococowa and Cane Creek discharges were based on Big Sand and Ascalmore Creeks while Strayhorn Creek flows were developed from Arkabutla Creek only. One drawback to this approach is that those ungaged sources with records developed from the same nearby stations will have identical hydrograph timing; the peak and low flows will occur on the same day. This may not be unrealistic, however, as such groups of watersheds are in close proximity to each other and have similar characteristics.

The other type of relationship used to estimate ungaged sources was flow continuity between a gaged site above the ungaged source inflow and a gaged site below the inflow. Again, discharge per unit area was employed as

$$Q_{UG} = A_{UG} \left[\frac{Q_{Below} - Q_{Above}}{A_{Below} - A_{Above}} \right] \qquad (20)$$

where Q_{Above} is the daily or weekly discharge at the site upstream of the ungaged inflow, Q_{Below} is the discharge downstream of the site and A_{Below} and A_{Above} are the drainage areas contributing to the two sites. Five sources were estimated using this approach. Batupan Bogue was estimated by Yalobusha River at Grenada Town (Highway 51), downstream, and Yalobusha River at Grenada Dam, upstream. Tillatoba, Peters and McIvor Drainage utilized the Panola-Quitman Floodway near Batesville and Little Tallahatchie River at Sardis Dam while Lake Cormorant Bayou used Coldwater River near Prichard and Coldwater River at Arkabutla Dam. If there was a loss between gaged stations at any particular time, a default value was used for the ungaged source discharge. Addition of these 14 ungaged sources to the 30 gaged sites produced a set of point source or specific site inputs or outputs. Non-point or undefined sources completed the flow records.

5.2 Non-Point Sources

Non-point source (NPS) inflows or outflows are comprised of several hydrologic units. Notable non-point sources are groundwater flow, overbank flow, low gradient backwater swamps, channels or bayous, small tributaries, or overland flow. To account for each of these sources would be an enormous task not worthwhile to this study. Therefore, each of these small or diffuse sources were lumped into non-point sources. Eighteen non-point sources were determined for this study, one for each reach or subreach as noted in the spatial design. Fifteen were developed between Belzoni and Arkabutla Dam and only three were developed downstream from Belzoni. Non-point source flows were computed by flow continuity or

$$Q_{NPS} = Q_{OUT} - \sum_{i=1}^{n} Q_{IN_i} \qquad (21)$$

where Q_{NPS} is the weekly or daily discharge for the non-point source, Q_{OUT} is the outflow station of the reach being processed, Q_{IN_i} is the individual inflow to the reach and n is the number of inflows. For example, the reach from Satartia to Yazoo City has an outflow site at Satartia and inflows from Short Creek (ungaged estimate) and Yazoo River at Yazoo City, all other sources are considered as part of non-point source flows. Because non-point sources can be either inflows or outflows there was no constraint upon discharge being positive or negative. A computer program for calculating non-point sources is presented in Appendix D. Statistics for ungaged and non-point sources are presented in Appendix C.

VI. SUMMARY AND CONCLUSIONS

The addition of 18 non-point sources to 30 gaged and 14 ungaged sites completed development of the Yazoo River discharge records needed for the water and sediment routing models. Much time and effort was spent in converting stage data on magnetic tapes, and printed data on graphs and in books into daily and weekly discharges. The approach and techniques devised for producing discharge files of the magnitude (over 400,000 values) needed for a large river basin study is one key component of this project. This approach will prove to be useful when other river basins are analyzed.

APPENDIX A

Schematic of Spatial-Temporal

Design for Yazoo River Basin

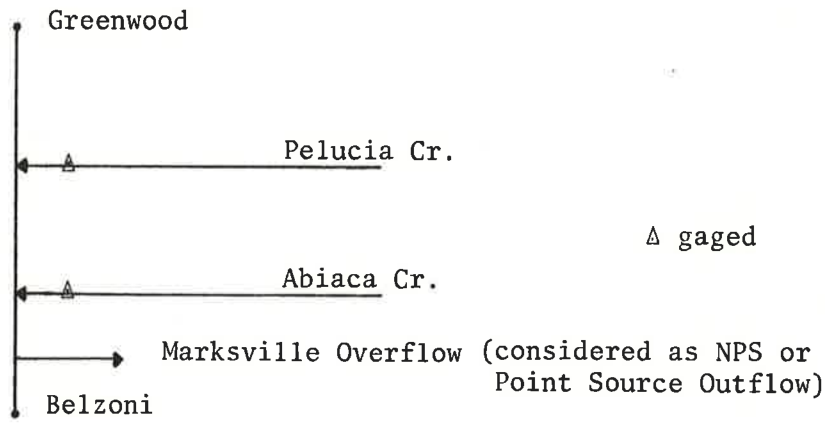
YAZOO RIVER BASIN MODEL STUDY

DISTRIBUTION OF FLOWS BY RIVER REACH

UPPER RIVER

REACH 1

Belzoni to Greenwood



Belzoni = Greenwood + Abiaca + Pelucia +*NPS1 (including Marksville Overflow)

Station[1]	R.M.[2]	Area[3]	Flow Records[4]	Remarks
Belzoni	116.2	7830	Yes, SD	Downstream Station
Abiaca Cr.	140.34	~112	Yes, SD	Planimetered Area
Pelucia Cr.	155.7	64	Yes, SD	Area at Gaging Station
Greenwood	166.0	7450	Yes	Key Station

Change in area = 7830 - 7450 = 380 sq. mi.

Gaged streams = 176 sq. mi. = 46.3 % of change in area

Non-Point Sources = 204 sq. mi. = 53.7%

1) Name of gaging station or tributary stream

2) River Mile

3) Drainage area above gaging station or area of tributaries, in sq. miles.

4) Availability of flow records and source

SD - COE stage records converted to discharge

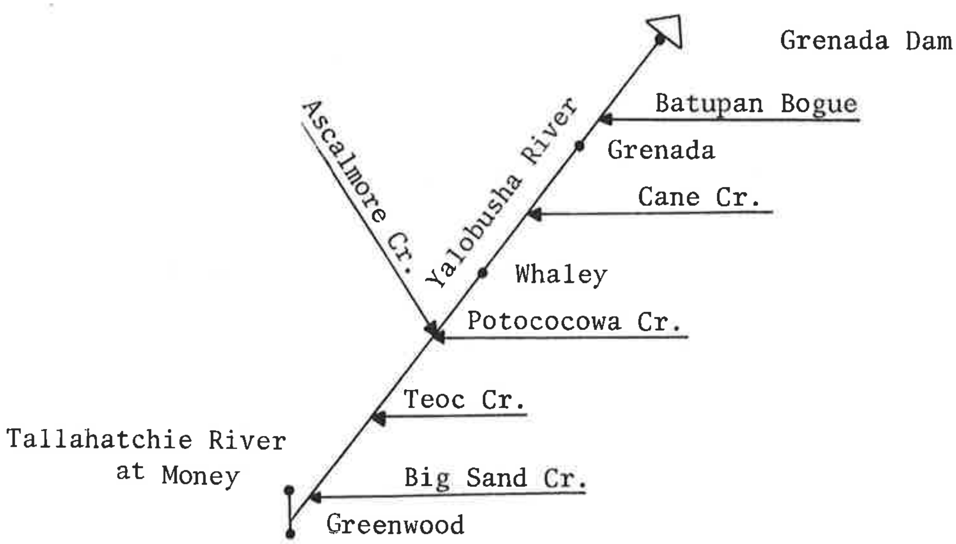
USGS - United States Geological Survey Daily Flow Records

*NPS - Non-point source inflows

REACH 2

Greenwood to Money includes Yalobusha River from Grenada Dam to Greenwood.

There are three subsections in this reach.



Subsection 1

Greenwood = Money + Whaley + Ascalmore + Big Sand + Teoc + Potococowa + NPS2

Station	R.M.	Area	Flow Records	Remarks
Greenwood	166	7450	Yes	Key Station
Big Sand Cr.	1.05*	110	Yes, SD	
Teoc Cr.	7.65*	40	No	
Potococowa Cr.	8.65*	78	No	
Ascalmore Cr.	8.77*	32	Yes, SD	
Yalobusha at Whaley	9.05*	1960	Yes, SD	
Money	192.9	5221	Yes, SD	

*Upstream on Yalobusha from confluence with Yazoo River

Change in area = 7450 - 5221 - 1960 = 269 sq. mi.

Ungaged Streams = 118 sq. mi. = 43.9%

Gaged streams = 142 sq. mi. = 52.8%

Non-Point Sources = 9 sq. mi = 3.3%

Subsection 2

Yalobusha River

Whaley to Grenada town (Highway 51)

Whaley = Grenada town + Cane Creek + NPS3

Station	R.M.	Area	Flow Records	Remarks
Whaley	9.05	1960	Yes, SD	
Cane Cr.	21.74	25	No	
Grenada town	45.59	1570	Yes, SD	

Change in area = 1960 - 1570 = 390 sq. mi.

Ungaged streams = 25 sq. mi. = 6.4%

Non-Point Sources = 365 sq. mi. = 93.6%

Subsection 3

Grenada town to Grenada Dam

Grenada town = Grenada Dam + Batupan Bogue + NPS4

Station	R.M.	Area	Flow Records	Remarks
Grenada town	45.59	1570	Yes, SD	
Batupan Bogue	46.60	162	No	
Grenada Dam	47	1320	Yes, USGS	

Change in area = 1570 - 1320 = 250 sq. mi.

Ungaged Streams = 162 sq. mi. = 64.8%

Non-Point Sources = 88 sq. mi. = 35.2%

REACH 3

Money to Swan Lake

Money = Swan Lake + NPS5

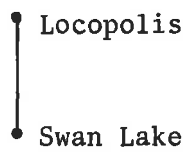
Station	R.M.	Area	Flow Records	Remarks
Money	192.90	5221	Yes, SD	
Swan Lake	219.08	5130	Yes, USGS	

Change in Area = 5221-5130 = 91 sq. mi.

Non-Point Sources = 91 sq. mi. = 100%

REACH 4

Swan Lake to Locopolis



Swan Lake = Locopolis + NPS6

Station	R.M.	Area	Flow Records	Remarks
Swan Lake	219.08	5130	Yes, USGS	
Locopolis	230.65	4920	Yes, SD	

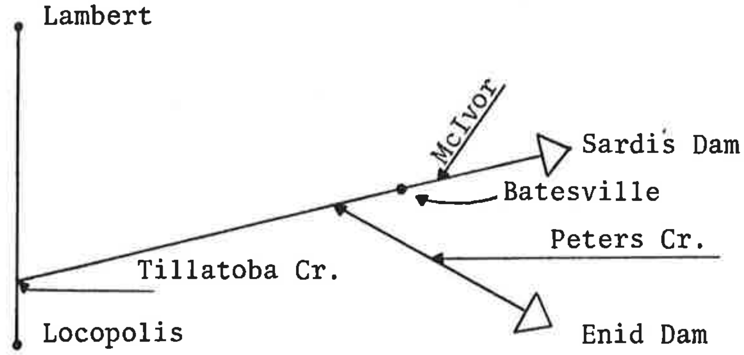
Change in Area = 5130 - 4920 = 210 sq. mi.

Non-Point sources = 210 sq. mi. = 100%

REACH 5

Locopolis to Lambert includes P-Q Floodway

There are two subsections in this reach



Subsection 1

Locopolis = Lambert + Batesville + Enid Dam + Peters Creek

+ Tillatoba Creek + NPS7

Station	R.M.	Area	Flow Records	Remarks
Locopolis	230.65	4920	Yes, SD	
Batesville	23.30*	1802	Yes, SD	
Enid Dam	13.5*	560	Yes, USGS	
Peters Cr.	6.1*	71	No	
Tillatoba Cr.	234.65	157	No	
Lambert	253.19	1980	Yes, USGS	

Change in Area = 4920 - 1802 - 560 - 1980 = 578 sq. mi.

Ungaged Streams = 228 sq. mi. = 39.4%

Non-Point Sources = 350 sq. mi. = 60.6%

* R.M. on P-Q, Yocona, or Little Tallahatchie

Subsection 2

Batesville = Sardis Dam + McIvor Drainage + NPS8

Station	R.M.	Area	Flow Records	Remarks
Batesville	23.30	1802	Yes, SD	
McIvor Drainage	24.74	76	No	
Sardis Dam	49.70	1545	Yes, USGS	

Change in Area = 1802 - 1545 = 257 sq. mi.

Ungaged Streams = 76 sq. mi. = 29.6%

Non-Point Sources = 181 sq. mi. = 70.4%

REACH 6

Lambert to Marks

Lambert = Marks + NPS9

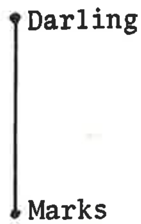
Station	R.M.	Area	Flow Records	Remarks
Lambert	253.19	1980	Yes, USGS	
Marks	261.4	1810	Yes, SD	

Change in Area - 1980 - 1810 = 170 sq. mi.

Non-Point Sources = 170 sq. mi. = 100% NPS9

REACH 7

Marks to Darling



Marks = Darling + NPS10

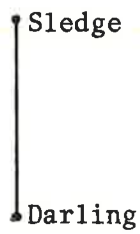
Station	R.M.	Area	Flow Records	Remarks
Marks	261.4	1810	Yes, SD	
Darling	272.5	1620	Yes, SD	

Change in Area - 1810 - 1620 = 190 sq. mi.

Non-Point Sources = 190 sq. mi. = 100% NPS10

REACH 8

Darling to Sledge



Darling = Sledge + NPS11

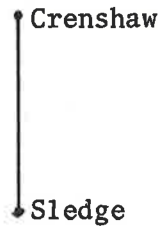
Station	R.M.	Area	Flow Records	Remarks
Darling	272.5	1620	Yes, SD	
Sledge	278.84	1404	Yes, SD	

Change in Area = 1620 - 1404 = 216 sq. mi.

Non-Point Source = 216 sq. mi. = 100% NPS11

REACH 9

Sledge to Crenshaw



Sledge = Crenshaw + NPS12

Station	R.M.	Area	Flow Records	Remarks
Sledge	278.84	1404	Yes, SD	
Crenshaw	284.00	1403	Yes, SD	

Change in Area = 1404 - 1403 = 1 sq. mi.

Non-Point Sources = 1 sq. mi. = 100% NPS12

REACH 10

Crenshaw to Sarah

Crenshaw = Sarah + NPS13

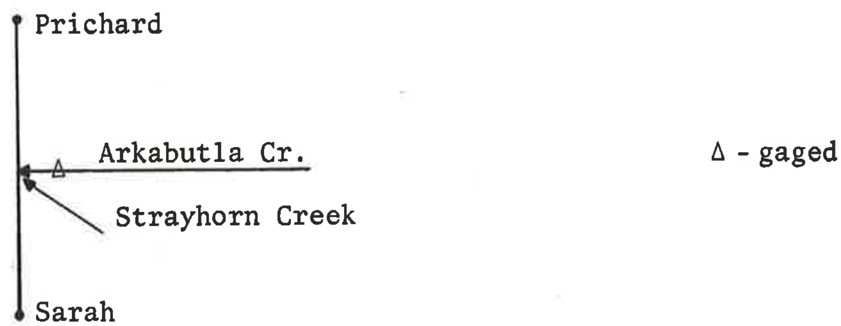
Station	R.M.	Area	Flow Records	Remarks
Crenshaw	284.0	1403	Yes, SD	
Sarah	288.7	1395	Yes, SD	

Change in Area = 1403 - 1395 = 8 sq. mi.

Non-Point Sources = 8 sq. mi. = 100% NPS13

REACH 11

Sarah to Prichard



Sarah = Prichard + Arkubutla Creek + Strayhorn Creek + NPS14

Station	R.M.	Area	Flow Records	Remarks
Sarah	288.7	1395	Yes, SD	
Arkubutla Cr.	291.2	104	Yes, SD	
Strayhorn Cr.		47	No	Location not fixed
Prichard	299.54	1214	Yes, SD	

Change in Area = 1395 - 1214 = 181 sq. mi.

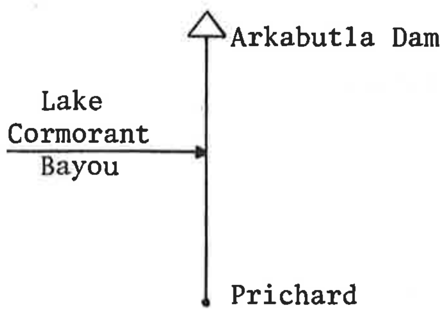
Gaged Streams = 104 sq. mi. = 57.5%

Ungaged Streams = 47 sq. mi. = 26.0%

Non-Point Sources = 30 sq. mi. = 16.5%

REACH 12

Prichard to Arkabutla Dam



Prichard = Arkabutla Dam + Lake Cormorant Bayou + NPS15

Station	R.M.	Area	Flow Records	Remarks
Prichard	299.54	1214	Yes, SD	
Lake Cormorant Bayou	301.8	101	No	
Arkabutla Dam	307.5	1000	Yes, USGS	Upstream Station

Change in Area = 1214 - 1000 = 214 sq. mi.

Ungaged streams = 101 sq. mi. = 47.2%

Non-Point Sources = 113 sq. mi. = 52.8%

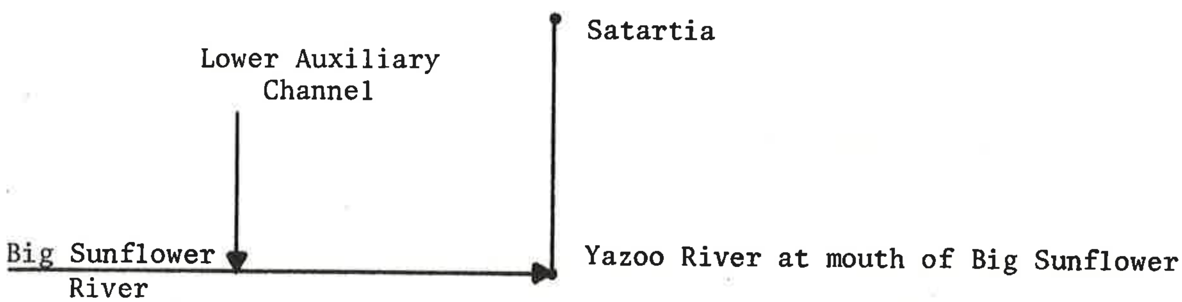
YAZOO RIVER BASIN MODEL STUDY

DISTRIBUTION OF FLOWS BY RIVER REACH

LOWER RIVER

REACH 1

Yazoo River at mouth of Big Sunflower to Satartia



Yazoo River at mouth of Big Sunflower = Satartia + Big Sunflower + NPS 953

Station	R. M.	Area	Flow Records	Remarks
Satartia	53.3	9020	Yes, SD	
Big Sunflower	44.4	*	No	
Yazoo River at mouth of Big Sunflower	44.4	*	Yes, SD	

Change in area = Undetermined

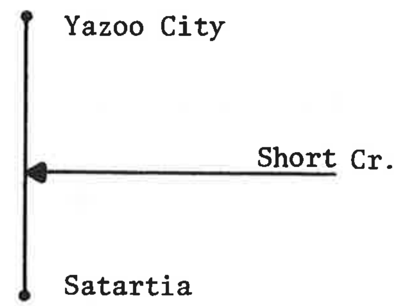
Ungaged Streams = Undetermined

Non Point Sources = Undetermined

* Undetermined

REACH 2

Satartia to Yazoo City



Satartia = Yazoo City + Short + NPS 952

Station	R. M.	Area	Flow Records	Remarks
Satartia	53.3	9020	Yes, SD	
Short	72.50	36	No	
Yazoo City	75.00	8900	Yes, SD	

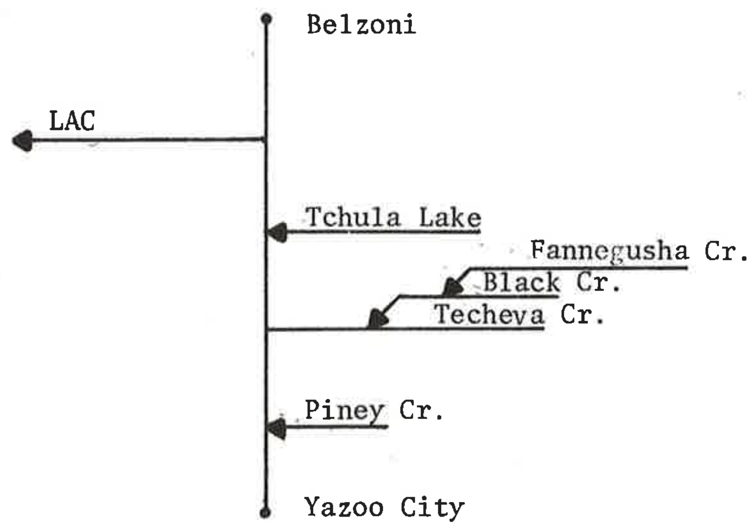
Change in Area = 9020 - 8900 = 120 sq. mi.

Ungaged Streams = 36 sq. mi. = 30%

Non-Point Sources = 84 sq. mi. = 70%

REACH 3

Belzoni to Yazoo City



Yazoo City = Piney + Techeva + Black + Fannegusha + Tchula Lake - LAC + Belzoni + NPS 953

Station	R. M.	Area	Records	Remarks
Yazoo City	75.0	8900	Yes, SD	
Piney Cr.	84.8	78	No	
Techeva Cr.	95.9	59	No	
Black Cr.	95.9	111	No	
Fannegusha Cr.	95.9	99	No	
Tchula Lake	105.2	*	Yes, SD	Stage records extended from Belzoni gage
Lower Auxiliary Channel Outflow	107.1	-	Yes, SD	Silver City gaged used to determine discharge
Belzoni	116.2	7830	Yes, SD	

Change in area = 1070 sq. mi.

Ungaged streams = 347 sq. mi. = 32.4%

Non-Point Sources = 723 sq. mi. = 67.6%

* Not determined

APPENDIX B

Stage-Discharge Parameters

PARAMETERS FOR YAZOO RIVER BASIN
STAGE-DISCHARGE RELATIONSHIPS

$$Q = a(S + c)^b$$

$$Q = mS + k$$

NAME	Parameter					Break-point Stage*
	a	b	c	k	m	
Yazoo River at mouth of Big Sunflower	923.322	1.007	-55.00	-	-	
Yazoo River at Satartia	804.407	.864	-	-	-	
Yazoo River at Yazoo City	679.170	.939	-	-	-	
Lower Auxiliary Channel overflow nr. Silver City[1]	960	1	-90	14400	1600	105
Tchula Lake Cut-off nr. Mileston[2]	-	-	-	-1819.32	586.83	
Yazoo River at Belzoni	154.80	1.457	-	-	-	
Yazoo River Over-flow at Marksville[3]	399.972	1	-25	-	-	
Abiaca Creek near Pine Bluff	30.594	2.120	-4	-33533.33	2433.33	16.40
Pelucia Creek near Valley Hill	58.843	2.373	-7.5	-29885.71	2485.71	14.12
Yazoo River at Greenwood	discharge already determined by USGS					
Tallahatchie River at Money	57.808	1.704	-3	-	-	
Big Sand Creek at Valley Hill	30.478	2.646	-1.5	-19571.43	1928.575	5.64
Ascalmore Creek at Paynes	8.492	2.615	-1	-7339.465	1161.564	7.17
Yalobusha River at Whaley	0.323	3.209	-	-251863.62	10344.30	25.34
Yalobusha River at Grenada	3.392	2.921	-	-	-	
Yalobusha River at Grenada Dam	discharge already determined by USGS					
Tallahatchie River near Swan Lake	discharge already determined by USGS					

NAME	Parameter a	b	c	k	m	Break-point Stage*
Tallahatchie River at Locopolis	65.578	1.717	-10	-145805.21	4953.34	32.14
Yocona River at Enid Dam	discharge already determined by USGS					
Little Tallahatchie River near Batesville	122.211	1.654	-	-91680.72	5880.49	18.09
Little Tallahatchie River at Sardis Dam	discharge already determined by USGS					
Tallahatchie River near Lambert	discharge already determined by USGS					
Coldwater River at Marks	6.301	2.280	-10	-	-	
Coldwater River near Darling	5.940	2.347	-3	-	-	
Coldwater River near Sledge	27.573	1.860	2	-	-	
Coldwater River near Crenshaw	29.549	2.030	2.5	-	-	
Coldwater River near Sarah	74.880	1.594	1.2	-32552.65	2181.99	19.07
Arkabutla Canal[4] near Arkabutla	2.944	2.566	-	-43900	2700	17.90
Coldwater River near Prichard	24.096	1.970	-7	-	-	
Coldwater River at Arkabutla Dam	discharge already determined by USGS					

Key -

* Stage at which dual stage-discharge relationships match.

[1] Two linear relationships used $Q = 960(S - 90)$ for $90 \leq S \leq 105$

$Q = 14400 + 1600\ (S - 105)$ for $S \geq 105$

[2] Linear relationship only of $Q = 586.83(S - 20) - 1819.32$

[3] Linear relationship only of $Q = 399.972(S - 25)$ for $S \geq 25$

4 Stages less than or equal to zero were assumed as no flow

APPENDIX C

Flow Statistics for Gaged,

Ungaged and Non-point Sources

Comparison of Flow Statistics for
11 years daily, 11 years weekly, and 50 years of weekly flows

Upper River

Station	Statistic	11 Years Daily	11 Years Weekly	50 Years Weekly
Belzoni	Max	28158.76	28114.91	28114.91
	Min	1339.75	1466.92	1466.92
	Mean	11335.60	11335.60	12183.22
	Std.Dev.	5777.74	5734.42	4436.44
Marksville overflow	Max	4239.97	4228.54	4228.54
	Min	.01	1.10	0.15
	Mean	297.67	298.51	83.96
	Std.Dev.	789.46	784.52	396.67
Abiacca Cr.	Max	10539.55	3948.73	3948.73
	Min	1.00	119.58	119.58
	Mean	476.89	476.89	457.86
	Std.Dev.	476.61	341.75	259.72
Pelucia Cr.	Max	6403.50	2379.39	2379.39
	Min	1.00	3.38	3.38
	Mean	208.78	208.78	150.99
	Std.Dev.	467.81	324.26	210.84
Greenwood	Max	43800.00	40857.14	40857.14
	Min	971.00	1065.71	1065.71
	Mean	11727.19	11727.19	12674.57
	Std.Dev.	6513.29	6426.53	4924.74
NPS1	Max	7364.89	6481.17	6481.17
	Min	-20330.43	-13843.61	-13843.61
	Mean	-1077.26	-1077.26	-1100.20
	Std.Dev.	2132.62	1897.64	1318.76
Money	Max	22830.88	22419.91	22419.91
	Min	516.73	561.00	561.57
	Mean	8145.13	8145.13	9183.14
	Std.Dev.	4785.18	4731.65	3860.66
Big Sand Cr.	Max	13919.67	7083.45	7083.45
	Min	16.89	23.65	23.65
	Mean	292.49	292.49	285.80
	Std.Dev.	835.58	598.69	509.29
Teoc Cr.	Max	3713.75	1722.54	1885.01
	Min	26.42	28.42	19.49
	Mean	148.27	148.27	136.26
	Std.Dev.	254.20	182.40	145.80
Potococowa Cr.	Max	7241.81	3358.95	3675.77
	Min	51.52	55.42	38.01
	Mean	289.12	289.12	265.70
	Std.Dev.	495.69	355.67	284.31
Ascalmore Cr.	Max	4333.67	1609.67	1609.67
	Min	1.00	7.09	7.09
	Mean	152.14	152.14	134.87
	Std.Dev.	237.91	159.64	105.10
Whaley	Max	22087.90	19427.96	19427.96
	Min	225.52	295.96	295.96
	Mean	2884.23	2884.23	2607.21
	Std.Dev.	2471.49	2424.75	1554.94
Cane Cr.	Max	2321.09	1076.59	1178.13
	Min	16.51	17.76	12.18
	Mean	92.67	92.67	85.16
	Std.Dev.	158.87	114.00	91.13
Grenada	Max	32415.49	12813.53	12813.53
	Min	43.75	54.60	54.60
	Mean	1972.50	1972.50	1754.88
	Std.Dev.	2165.90	1850.21	1521.37
Butupan Bogue	Max	21002.00	8183.94	8183.94
	Min	.06	.57	.19
	Mean	399.33	373.17	283.27
	Std.Dev.	1013.22	714.64	472.37
Grenada Dam	Max	6510.00	5685.71	5685.71
	Min	5.00	5.00	5.00
	Mean	1837.74	1837.74	1677.91
	Std.Dev.	1447.49	1381.19	1197.99
NPS2	Max	4592.03	2636.33	2636.33
	Min	-31638.51	-45808.51	-15808.51
	Mean	-184.20	-184.20	61.58
	Std.Dev.	2244.82	1856.51	1434.27
NPS3	Max	20090.50	16224.96	16224.96
	Min	-19218.66	-3243.69	-6024.33
	Mean	819.06	819.06	767.17
	Std.Dev.	1993.63	1595.03	1026.68
NPS4	Max	11408.49	4445.59	4445.59
	Min	-2179.63	-1284.83	-206.30
	Mean	-264.56	-238.40	-1614.37
	Std.Dev.	772.84	633.21	489.13

Upper River Weekly Flows-continued

Station	Statistic	11 Years Daily	11 Years Weekly	50 Years Weekly
Swan Lake	Max	44900.00	36428.57	36428.57
	Min	612.00	774.14	774.14
	Mean	7929.28	7929.28	8917.06
	Std.Dev.	4857.45	4750.23	3842.77
NPS5	Max	5298.14	5164.42	5164.42
	Min	-22780.45	-14816.10	-14816.10
	Mean	215.86	215.86	266.08
	Std.Dev.	1643.91	1509.93	880.97
Locopolis	Max	33753.37	29802.49	29802.49
	Min	650.53	713.15	713.15
	Mean	7291.47	7291.47	8260.64
	Std.Dev.	4767.61	4685.40	3641.99
NPS6	Max	12054.75	6626.08	6626.08
	Min	-4122.35	-2124.90	-2124.90
	Mean	637.81	637.81	656.42
	Std.Dev.	842.32	720.32	455.69
Lambert	Max	15100.00	14571.43	14571.43
	Min	85.00	116.43	116.43
	Mean	2843.12	2843.12	3400.68
	Std.Dev.	2785.66	2670.86	2681.66
Tillatoba Cr.	Max	12577.58	4185.72	4185.72
	Min	.12	0.02	0.02
	Mean	458.44	448.73	621.04
	Std.Dev.	830.75	561.25	429.67
Enid Dam	Max	4510.00	3925.71	3925.71
	Min	5.00	5.00	1.20
	Mean	940.23	939.90	950.62
	Std.Dev.	790.48	751.32	827.30
Peters Cr.	Max	5687.95	1892.91	1892.91
	Min	.06	0.01	0.01
	Mean	207.23	202.93	280.85
	Std.Dev.	375.69	253.81	194.31
Batesville	Max	21444.78	13815.14	13815.14
P-Q Floodway	Min	78.91	96.67	96.67
	Mean	3139.52	3139.52	3545.70
	Std.Dev.	2100.59	1858.89	1919.34
Sardis Dam	Max	11900.00	10997.14	10997.14
	Min	15.00	15.00	15.00
	Mean	2425.86	2424.74	2557.92
	Std.Dev.	1676.13	1588.02	1880.29
McIvor Drainage	Max	6088.51	2026.21	2026.21
	Min	.06	0.01	0.01
	Mean	221.92	217.22	300.63
	Std.Dev.	402.15	271.69	207.99
NPS7	Max	12883.41	7118.75	7118.75
	Min	-33045.56	-3942.66	-16959.32
	Mean	-297.07	-282.75	-538.26
	Std.Dev.	2674.60	1906.34	2287.05
NPS8	Max	15006.54	4825.58	4825.58
	Min	-2317.98	-542.32	-542.32
	Mean	491.74	497.56	687.15
	Std.Dev.	1112.19	663.52	542.38
Marks	Max	15152.42	14854.86	14854.86
	Min	214.70	219.50	219.50
	Mean	2974.33	2974.33	3486.62
	Std.Dev.	2826.98	2747.32	2463.54
NPS9	Max	4167.85	1477.78	3439.12
	Min	-3459.24	-2045.71	-2045.71
	Mean	-131.21	-131.21	-85.93
	Std.Dev.	620.54	550.42	447.33
Darling	Max	14795.23	14686.54	14686.54
	Min	153.73	154.82	154.82
	Mean	2322.37	2322.37	2677.74
	Std.Dev.	2626.63	2538.88	2306.04
NPS10	Max	3335.05	2854.46	2854.46
	Min	-4880.36	-1222.18	-1222.18
	Mean	651.96	651.96	808.88
	Std.Dev.	521.18	462.46	314.99
Sledge	Max	11376.99	11091.25	11091.25
	Min	100.11	100.11	100.11
	Mean	2034.47	2034.47	2317.91
	Std.Dev.	1779.88	1695.95	1581.18
NPS11	Max	10492.78	9275.45	9275.45
	Min	-2449.25	-1095.45	-1095.45
	Mean	287.90	287.90	359.83
	Std.Dev.	1064.85	1001.45	805.52
Crenshaw	Max	14398.82	13631.35	13631.35
	Min	1.32	41.75	41.75
	Mean	2063.29	2063.29	2375.11
	Std.Dev.	1957.51	1813.23	1831.92

Upper River Weekly Flows-continued

Station	Statistic	11 Years Daily	11 Years Weekly	50 Years Weekly
NPS12	Max	5083.17	2954.02	2954.02
	Min	-9329.93	-7233.88	-7233.88
	Mean	-28.82	-28.82	-57.20
	Std.Dev.	652.06	542.73	406.62
Sarah	Max	15676.88	13949.71	13949.71
	Min	29.45	77.42	77.42
	Mean	1855.67	1855.67	2230.95
	Std.Dev.	1752.80	1609.35	1669.44
NPS13	Max	7604.51	2798.56	2798.56
	Min	-4966.82	-1216.69	-1216.69
	Mean	207.63	207.63	144.16
	Std.Dev.	421.13	344.49	239.36
Strayhorn Cr.	Max	5543.09	4617.86	4617.86
	Min	0.05	0.45	0.45
	Mean	96.15	96.38	131.45
	Std.Dev.	462.51	389.62	555.39
Arkabutla Cr.	Max	12265.57	5061.57	5061.57
	Min	.01	.02	106.65
	Mean	170.72	164.41	105.26
	Std.Dev.	814.91	534.28	467.34
Prichard	Max	13584.13	13030.41	13030.41
	Min	35.49	47.27	47.27
	Mean	1750.69	1750.69	2098.88
	Std.Dev.	1729.77	1648.80	1712.65
NPS14	Max	4923.99	1900.78	1900.78
	Min	-17637.52	-13332.64	-16199.09
	Mean	-203.94	-204.68	-290.26
	Std.Dev.	1351.74	1158.42	1793.33
Lake Cormorant Bayou	Max	4502.44	2674.14	3130.18
	Min	.05	0.09	0.09
	Mean	204.04	203.48	262.27
	Std.Dev.	458.11	386.50	314.15
Arkabutla Dam	Max	10200.00	7675.71	7675.71
	Min	5.00	5.00	5.00
	Mean	1338.75	1338.75	1557.72
	Std.Dev.	1203.91	1141.00	1278.14
NPS15	Max	5037.39	2991.86	3502.08
	Min	-812.24	-201.05	-201.05
	Mean	207.90	208.47	278.89
	Std.Dev.	524.15	443.53	365.93

Lower River

Belzoni	Max	28158.76	28114.91	28114.91
	Min	1339.75	1466.92	1466.92
	Mean	11335.60	11335.60	12183.22
	Std.Dev.	5777.74	5734.42	4436.44
Tchula Lake	Max	5926.84	5854.18	5854.18
	Min	1.00	1.10	1.10
	Mean	786.22	786.24	903.76
	Std.Dev.	1127.30	1109.72	1246.92
LAC	Max	17120.00	17062.86	17062.86
	Min	.01	1.10	0.40
	Mean	2856.75	2857.23	2898.84
	Std.Dev.	4234.84	4202.31	4828.42
Fannegusha Cr.	Max	7935.12	2894.04	2894.04
	Min	.97	110.40	69.20
	Mean	321.45	321.45	282.85
	Std.Dev.	428.04	300.06	216.15
Black Cr.	Max	13946.58	5086.49	5086.49
	Min	1.70	194.04	121.62
	Mean	564.98	564.98	497.14
	Std.Dev.	752.31	527.38	380.45
Tescheva Cr.	Max	4729.01	1724.73	1724.73
	Min	.58	65.80	41.24
	Mean	191.57	191.57	168.57
	Std.Dev.	255.09	178.82	129.00
Piney Cr.	Max	6251.91	2280.15	2280.15
	Min	.76	86.99	54.52
	Mean	253.27	253.27	222.85
	Std.Dev.	337.24	236.41	170.54
Yazoo City	Max	19656.32	19605.04	19605.04
	Min	2000.00	2086.55	2086.55
	Mean	9229.60	9229.60	9709.58
	Std.Dev.	3929.38	3895.01	3078.39
NPS951	Max	5329.25	5197.94	10230.27
	Min	-28764.87	-8045.81	-8977.73
	Mean	-1366.75	-1366.28	-1649.98
	Std.Dev.	2314.57	1907.53	2447.80

Lower River Weekly Flows-continued

Station	Statistic	11 Years Daily	11 Years Weekly	50 Years Weekly
Short Cr.	Max	2885.50	1052.38	1052.38
	Min	.35	40.15	25.16
	Mean	116.89	116.89	102.86
	Std.Dev.	155.65	109.11	78.71
Satartia	Max	20142.66	20122.68	20122.68
	Min	2000.00	2000.00	2000.00
	Mean	9410.73	9410.73	9891.98
	Std.Dev.	4218.92	4184.54	3499.55
NPS952	Max	3882.46	3072.02	3072.02
	Min	-6001.64	-2053.86	-2053.86
	Mean	64.24	64.24	79.54
	Std.Dev.	811.45	765.18	602.28
Yazoo River at Mouth Big Sunflower	Max	44171.82	44155.87	44155.87
	Min	2245.98	2411.04	2411.04
	Mean	18816.81	18816.81	19723.91
	Std.Dev.	9563.75	9496.20	8098.45
NPS953	Max	15910.47	15171.09	15171.09
	Min	-466.66	409.94	-2365.22
	Mean	6549.34	6548.85	6933.10
	Std.Dev.	2806.63	2742.70	3152.09

APPENDIX D

Computer Programs Used in Developing Actual and Generated Discharge Records

Program for Converting Stages to Discharges and Computing Daily Flows

```
      PROGRAM SD(INPUT,OUTPUT,TAPE1,TAPE2,TAPE5=INPUT,TAPE6=OUTPUT)
CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC
C                                                                          C
C      THIS  PROGRAM DECODES STAGES FROM TAPE1,CONVERTS STAGES TO  DISCHARGES, C
C      FILLS IN MISSING DISCHARGES, COMPUTES AVERAGE DAILY DISCHARGES,     C
C      AND COMPUTES THE MEAN, MEAN LOG, STD DEV,LOG STD DEV, AND RANGE OF  C
C      THE CREATED DAILY DISCHARGES.                                       C
C                                                                          C
C     LIST OF VARIABLES                                                    C
C     S= STAGE AT 8AM                                                      C
C     A =CONSTANT TO BE READ / B= CONSTANT TO BE READ / C = CONSTANT TO BE READ C
C     DISCHARGE = A * (AVERAGE STAGE + C) ** B                             C
C     D = DISCHARGE COMPUTED FROM S - D RELATION      DM = MEASURED DISCHARGE  C
C     ICHECK = STATION CODE BEING CONVERTED TO DISCHARGES.                 C
C     NCHECK IS A PARAMETER TO CAUSE LINE AFTER BAD CODE TO BE PRINTED ALSO.  C
C                                                                          C
CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC
      DIMENSION S(4018),Q(4018)
      INTEGER SIT1,S1
       INTEGER DMINC
C
C      READ IN STATION CODE NUMBER
C
      READ(5,510) ICHECK
C
C      READ IN NFUNC WHICH TELLS IF ANY LINEAR EQUATIONS ARE USED TO
C      RELATE STAGE TO DISCHARGE
C
      READ(5,500) NFUNC
C
C      READ PARAMETERS  FOR NON-LINEAR EQUATION ALONG WITH MAXIMUM AND
C      MINIMUN EXPECTED VALUES
C
         READ(5,200)A,B,C,DMAX,DMIN
      C1=1$C2=2$STGCHEK=100000.
C
C      READ IN PARAMETERS FOR LINEAR EQUATION  AND BREAKPOINT  D=C1*STG-C2
C
      IF(NFUNC.GT.0) READ(5,200)C1,C2,STGCHEK
      DMINC=0
      NZSK=0
      KOUNT=0
      READ(1,95) ISTA
   95 FORMAT(I5)
      PRINT 97,ISTA
   97 FORMAT(///20X*STATION NUMBER*I5//)
C
C      READ IN STAGE DATA
C
  777 CONTINUE
         READ(1,100)ICODE,IMO,IDAY,IYEAR,SIT1,MCODE,S8,S1,S2,DM
         IF(EOF(1))99,15
C
C      CHECK TO SEE IF NEGATIVE STAGE
C
   15 IF(MCODE.NE.1H ) S8=S8*(-1.)
      KOUNT=KOUNT+1
      S(KOUNT)=S8
      STG=S8
         IF (ICODE.NE.ICHECK) WRITE(6,900) ICODE,IDAY,IMO,IYEAR,SIT1,S8,
     1S1,S2,DM
      X=STG+C
      IF(X.LE.0.0.OR.SIT1.EQ.1HA) GO TO 77
      IF(NFUNC.EQ.0.OR.STG.LE.STGCHEK) D=A*(STG+C)**B
      IF(NFUNC.GT.0.AND.STG.GT.STGCHEK) D=C1*STG-C2
      GO TO 17
   77 NZSK=NZSK+1
      D=0.0
   17 CONTINUE
C
C      CHECK FOR MAX AND MIN
C
         IF (D.GE.DMAX) PRINT 600,ICODE,IDAY,IMO,IYEAR,D
      IF(D.GT.DMAX.AND.D.LT.999999.) D=DMAX
      IF(D.LE.DMIN) D=DMIN
```

```
      IF(D.LT.DMIN) DMINC=DMINC+1
      IF(IDAY.EQ.1.AND.IMO.EQ.1) WRITE(6,300) ICODE,IDAY,IMO,IYEAR,SIT1,
     *S8,S1,S2,STG,D
      Q(KOUNT)=D
      GO TO 777
   99 CONTINUE
      IF(DMINC.GT.0) PRINT 700,DMINC
      IF(NZSK.GT.0) PRINT 550,NZSK
  100 FORMAT(I6,3I2,A1,A1,F5.2,A1,F6.2,11X,F7.0)
  200 FORMAT(8F10.0)
  300 FORMAT(1H ,5X*FIRST VALUE OF A NEW YEAR*5X,I6,3I2,A1,F7.2,A1,F7.2,
     *1X,F7.2,3X,F7.0)
  500 FORMAT(8I10)
  510 FORMAT(16)
  550 FORMAT(1H ,*+++  NUMBER OF ADJUSTED STAGES LE ZERO +++*I5)
  600 FORMAT(1H ,* +++ +++ WARNING - THE COMPUTED DISCHARGE IS GREATER*,
     */5X* THAN OR EQUAL TO THE MAXIMUM DISCHARGE.  CODE -*I6*  DAY -*,
     *I2*  MONTH-*I2*  YEAR-*I2*  DISCHARGE = *F7.0)
  700 FORMAT(1H ,*+++NUMBER OF SUBMINIMUM FLOWS+++    *I5)
  900 FORMAT(1H , 5X,* FLOW CARD *,5X,I6,3I2,A1,F7.2,A1,F7.2,1X,F9.2)
      IF(KOUNT.NE.4018) PRINT 950, KOUNT
  950 FORMAT(10X*ERROR IN NUMBER OF VALUES*I5///)
      IF(KOUNT.NE.4018) GO TO 199
      N=KOUNT
      CALL QSET(Q,N)
      WRITE(2) ISTA,Q
  199 STOP
      END
      SUBROUTINE QSET(Q,NUMQ)
C
C      THIS SUBROUTINE COORDINATES SUBROUTINES TO FILL MISSING SPACES,
C      COMPUTE DAILY DISCHARGES,AND COMPUTE STATISTIC FOR DAILY DISCHARGES
C
      DIMENSION Q(4018)
      CALL QFILL(Q,NUMQ)
      CALL QDAVG(Q,NUMQ)
      CALL QSTATS(Q,NUMQ)
      PRINT 333,(Q(I),I=3653,4018)
  333 FORMAT(8F10.2)
       RETURN
      END
      SUBROUTINE QFILL(Q,N)
C
C      THIS SUBROUTINE FILLS IN MISSING VALUES BY AVERAGING THE
C      SURROUNDING  DISCHARGES
C
      DIMENSION Q(4018)
      I=0$KOUNT=0
      IF(Q(1).LE.0.0.OR.Q(1).GE.999999.) Q(1)=1.
      IF(Q(1).EQ.999999.) Q(1)=2.*Q(2)-Q(3)
   75 CONTINUE
      NSTART=0$NB=0$NF=0
   77 I=I+1
      NEND=N+1
      IF(I.EQ.NEND) GO TO 999
      IF(Q(I).LT.999999.) GO TO 100
      IF(NSTART.LE.0) NB=I-1
      NSTART=1
      GO TO 77
  100 IF(NSTART.LE.0) GO TO 77
      NF=I
      SLOPE=(Q(NF)-Q(NB))/FLOAT(NF-NB)
      KOUNT=KOUNT+NF-NB-1
      DO 50 K=NB,NF
      Q(K)=Q(NB)+SLOPE*(K-NB)
   50 CONTINUE
      GO TO 75
  999 CONTINUE
      IF(Q(N).EQ.999999.) Q(N)=2.* Q(N-1)-Q(N-2)
      IF(Q(N).LE.0.0.OR.Q(N).GE.999999.) Q(N)=1.
      PRINT 200,KOUNT
  200 FORMAT(5X*NO. OF FILLS=*I5)
      RETURN
      END
      SUBROUTINE QDAVG(Q,N)
```

```
C
C       THIS SUBROUTINE MAKES DATA INTO AVERAGE DAILY DISCHARGES BY
C       INTERPOLATING THE PREVIOUS AND SUBSEQUENT 12 MIDNIGHT DISCHARGES
C
      DIMENSION Q(4018),QAVG(4018)
      Q1=Q(1)-(Q(2)-Q(1))/3
      Q2=Q(1)+(Q(2)-Q(1))*(2/3)
      IF(Q1.LE.0.0) PRINT 200,Q1
  200 FORMAT(5X*ERROR IN FIRST VALUE*F12.0)
      IF(Q1.LE.0.0) GO TO 20
      QAVG(1)=(Q1+Q2)/2
   20 CONTINUE
      DO 100 I=2,4017
      QB=Q(I)-(Q(I)-Q(I-1))/3
      QF=Q(I)+(Q(I+1)-Q(I))*2/3
      QAVG(I)=(QB+QF)/2
  100 CONTINUE
      Q1=Q(N)-(Q(N)-Q(N-1))/3
      Q2=Q(N)+(Q(N)-Q(N-1))*(2/3)
      IF(Q2.LT.0.0) PRINT 210,Q2
  210 FORMAT(5X*ERROR IN LAST VALUE*F12.0)
      IF(Q2.LE.0.0) GO TO 30
       QAVG(N)=(Q1+Q2)/2
   30 CONTINUE
      DO 150 I=1,N
      Q(I)=QAVG(I)
  150 CONTINUE
      RETURN
      END
      SUBROUTINE QSTATS(Q,N)
C
C       THIS SUBROUTINE CALCULATES THE STATISTICS FOR THE DAILY DISCHARGE DATA
C
      DIMENSION Q(4018)
      SUM=0.$SUM2=0.$SUML=0.$SUML2=0.
      KSL=0$QMIN=1000000.$QMAX=-1000000.
C
C       FIND THE RANGE
C
      DO 100 I=1,N
      SUM=SUM+Q(I)
      IF(Q(I).GE.QMAX) QMAX=Q(I)
      IF(Q(I).LE.QMIN) QMIN=Q(I)
      IF(Q(I).LE.0.0) GO TO 100
      D=ALOG(Q(I))
      SUML=SUML+D
      KSL=KSL+1
  100 CONTINUE
C
C       COMPUTE MEAN AND LOG MEAN
C
      QAS=SUM/FLOAT(N)
      QASL=SUML/FLOAT(KSL)
      DQ=(QMAX-QMIN)/10.
      DO 150 I=1,N
      SUM2=SUM2+(Q(I)-QAS)*(Q(I)-QAS)
      IF(Q(I).LE.0.) GO TO 150
      D=ALOG(Q(I))
      SUML2=SUML2+(D-QASL)*(D-QASL)
  150 CONTINUE
C
C       COMPUTE STD DEV AND LOG STD DEV
C
      SUM2=SQRT(SUM2/FLOAT(N-1))
      SUML2=SQRT(SUML2/FLOAT(KSL-1))
      S=EXP(QASL)
C
C       COMPUTE PLUS AND MINUS ONE DEVIATION
C
      S1=EXP(QASL-SUML2)
      S2=EXP(QASL+SUML2)
      CUMPKNQ=0.0
      PRINT 190,QMAX,QMIN
  190 FORMAT(//20X* FLOW STATISTICS*/5X*MAX Q=*F8.2/5X*MIN Q=*F8.2/)
      PRINT 200, QAS,SUM2,QASL,SUML2,S,S1,S2,KSL
```

```
200 FORMAT(5X*MEAN DAILY FLOW=*F15.2/5X*STD.DEV. OF FLOW=*F15.2//
   15X*MEAN OF LOG FLOW=*F15.6/5X*DEV. OF LOG FLOW=*F15.6//
   25X*TRANSFORMED MEAN OF LOG FLOW=*F15.2/5X*MINUS ONE DEVIATION=*F15
   3.2/5X*PLUS ONE DEVIATION=*F15.2/5X*NUMBER OF NON ZERO FLOWS=*I5/)
    RETURN
    END
```

Program for Computing Weekly Discharges

```
      PROGRAM PWEEK(INPUT,OUTPUT,PUNCH,TAPE2=PUNCH,TAPE7,TAPE1)
C
C      THIS PROGRAM PRODUCES WEEKLY VALUES FROM DAILY VALUES .  IT ALSO
C      CALCULATES THE STATISTICS OF THE DATA.
C
      INTEGER WF
      REAL LWK
      COMMON/WEEKD/Q(4018),WK(574),LWK(574),XMEAN(11),XSTDV(11),NYEAR
      READ 150,ISTA
  150 FORMAT(I5)
      NI=5    $    NO=6
      WF=1
      NYEAR=11
      READ(WF) N,(Q(I),I=1,4018)
C   ---    CALCULATE MEAN AND STDV OF YEARLY FLOW    ---
      N=0
      DO 20 I=1,NYEAR
      NPTS=365
      IF(I.EQ.1.OR.I.EQ.5.OR.I.EQ.9) NPTS=366
      SUM=SSQ=0.
      FN=FLOAT(NPTS)    $    FN1=FN-1.
      DO 10 J=1,NPTS
      N=N+1
      SUM=SUM+Q(N)
   10 SSQ=SSQ+Q(N)*Q(N)
      XMEAN(I)=SUM/FN
      SSQ=SSQ/FN
      XSTDV(I)=SQRT((SSQ-XMEAN(I)*XMEAN(I))*(FN/FN1))
   20 CONTINUE
      PRINT 30,(I,XMEAN(I),XSTDV(I),I=1,NYEAR)
   30 FORMAT(5X,I2,5X,F10.2,5X,F10.2)
      SUMX=0.0
      DO 77 I=1,11
      SUMX=SUMX+ALOG(XMEAN(2))
   77 CONTINUE
      AVGQ=SUMX/11.
      PRINT 76,AVGQ
   76 FORMAT(2X,*AVERAGE LN Q*F12.6)
C   ---    CALCULATE WEEKLY FLOW    ---
      KOUNT=0    $    ITER=0    $    SUM=0.
      N=0
      DO 50 I=1,NYEAR
      NPTS=365
      IF(I.EQ.1.OR.I.EQ.5.OR.I.EQ.9) NPTS=366
      DO 40 J=1,NPTS
      KOUNT=KOUNT+1
      N=N+1
      SUM=SUM+Q(N)
      IF(KOUNT.EQ.7) GO TO 35
      GO TO 40
   35 ITER=ITER+1
      WK(ITER)=SUM/7.
      XX=WK(ITER)
      IF(XX.LT.1.) XX=1.
      LWK(ITER)=ALOG(XX)
      KOUNT=0    $    SUM=0.
   40 CONTINUE
   50 CONTINUE
      NDATA=ITER
      WRITE(7,150) ISTA
      WRITE(7,60)(WK(I),I=1,NDATA)
   60 FORMAT(8F10.2)
      WRITE(7,70)(LWK(I),I=1,NDATA)
   70 FORMAT(8F10.5)
      STOP
      END
```

Program for Fitting a Time Series to Weekly Discharges

```
      PROGRAM TSERIES(INPUT,OUTPUT,TAPE5=INPUT,TAPE6=OUTPUT,TAPE1,TAPE2,
C
C      THIS IS A TIME SERIES ANALYSIS   WHICH GENERATES  FIFTY YEARS
C      OF AVERAGE WEEKLY FLOW FROM ELEVEN YEARS OF AVERAGE WEEKLY FLOW
C
     1TAPE3)
      DIMENSION W1(13),W2(13),W3(13),W4(13)
      COMMON/WORK/C1(574),C2(574),TEMP(2609)
      COMMON/GFUNC/X(574,12),Y(574) ,YHAT(574),NDATA,B(12),AZERO,NA,NN,
     1 N2,NYEAR,YMEAN(52),YSTDV(52)
      COMMON/FILTER/H(3),GAIN(3),P(3,3),Q(3,3),R,U,V
      NI=5   $   NO=6
      NDATA=574
      NYEAR=11
C   ---   READ INPUT DATA   ---
      READ(1,10)(Y(I),I=1,NDATA)
   10 FORMAT(8F10.2)
      REWIND1
C   ---   FIND UPPER AND LOWER LIMITS   ---
      CALL MINMAX(QLOW,QHIGH)
      WRITE(NO,11) QLOW,QHIGH
   11 FORMAT(/,5X,*QLOW = *,F10.2,10X,*QHIGH = *,F10.2/)
C   ---   TRANSFORM TO LOGARITHM   ---
      DO 12 I=1,NDATA
      YY=Y(I)
   12 Y(I)=ALOG(YY)
      WRITE(NO,60)(Y(I),I=1,NDATA)
   60 FORMAT(10(3X,F10.2))
      CALL DSTAT(NDATA,Y,QMEAN,QSTDV,QLAG1)
      WRITE(NO,80) QMEAN,QSTDV,QLAG1
C   ---   STANDARDIZATION   ---
      CALL TREND
      DO 55 I=1,NDATA
   55 TEMP(I)=Y(I)
      WRITE(NO,60)(Y(I),I=1,NDATA)
      CALL MINMAX(QL,QH)
      WRITE(NO,11) QL,QH
C   ---   CYCLICAL COMPONENT IDENTIFICATION AND ELIMINATION   ---
      NA=12   $   NA1=NA+1
      NN=NA*NA
      TWOPI=8.*ATAN(1.)
      DO 30 I=1,NDATA
      FI=FLOAT(I)
      W=TWOPI*FI/26.
      X(I,1)=COS(W)
      X(I,2)=SIN(W)
      X(I,3)=COS(2.*W)
      X(I,4)=SIN(2.*W)
      X(I,5)=COS(3.*W)
      X(I,6)=SIN(3.*W)
      X(I,7)=COS(4.*W)
      X(I,8)=SIN(4.*W)
      X(I,9)=COS(5.*W)
      X(I,10)=SIN(5.*W)
      X(I,11)=COS(6.*W)
      X(I,12)=SIN(6.*W)
   30 CONTINUE
      CALL LINREG
      DO 32 I=1,12
   32 W2(I)=B(I)
      W2(13)=AZERO
      DO 50 I=1,NDATA
      DY=Y(I)-YHAT(I)
   50 Y(I)=DY
      YY1=Y(574)   $   YY2=Y(573)
      WRITE(NO,60)(Y(I),I=1,NDATA)
C   ---   CALCULATION OF RESIDUAL STATISTICS   ---
      CALL DSTAT(NDATA,Y,RMEAN,RSTDV,RLAG1)
      WRITE(NO,80) RMEAN,RSTDV,RLAG1
   80 FORMAT(/,5X,*RMEAN = *,F10.5,10X,*RSTDV = *,F10.5,10X,*RLAG1 = *,
     1F10.5/)
      CALL MINMAX(QMIN,QMAX)
```

```
      WRITE(NO,80) YMEAN1,YSTDV1,YLAG1
      CALL LINREG
      DO 130 I=1,12
  130 W3(I)=B(I)
      W3(13)=AZERO
      DO 135 I=1,NDATA
      C1(I)=YHAT(1)
  135 Y(I)=C2(I)
      CALL DSTAT(NDATA,Y,YMEAN2,YSTDV2,YLAG2)
      DO 134 I=1,NDATA
      YY=(Y(I)-YMEAN2)/YSTDV2
  134 Y(I)=YY
      WRITE(NO,80) YMEAN2,YSTDV2,YLAG2
      CALL LINREG
      DO 136 I=1,12
  136 W4(I)=B(I)
      W4(13)=AZERO
      DO 138 I=1,NDATA
  138 C2(I)=YHAT(I)
    ---    DISCHARGE GENERATION   ---
      NDATA=NDATA+2035
      DO 100 I=575,NDATA
      FI=FLOAT(I)
      CALL HARMON(W,FI,W2,YH2)
      CALL HARMON(W,FI,W3,CF1)
      COEF1=CF1*YSTDV1+YMEAN1
      CALL HARMON(W,FI,W4,CF2)
      COEF2=CF2*YSTDV2+YMEAN2
      READ(3) RX
      YY=COEF1*YY1+COEF2*YY2+RSTDV*RX*SQRT(1.-RLAG1*RLAG1)
      IF(YY.GT.QMAX) YY=QMAX
      IF(YY.LT.QMIN) YY=QMIN
      YT=YY+YH2
      IF(YT.GT.QH) YT=QH
      IF(YT.LT.QL) YT=QL
   98 YY2=YY1
      YY1=YY
      TEMP(I)=YT
  100 CONTINUE
C   ---    CONVERT LOG-VALUES TO CFS   ---
      N=0    $    NYEAR=50
      DO 102 J=1,NYEAR
      DO 102 I=1,52
      N=N+1
      TEMP(N)=TEMP(N)*YSTDV(I)+YMEAN(I)
  102 CONTINUE
      DO 104 I=1,9
      K=I+2600
  104 TEMP(K)=TEMP(K)*YSTDV(I)+YMEAN(I)
      DO 110 I=1,NDATA
      YY=TEMP(I)
      TEMP(I)=EXP(YY)
      IF(TEMP(I).GT.QHIGH) TEMP(I)=QHIGH
      IF(TEMP(I).LT.QLOW) TEMP(I)=QLOW
  110 CONTINUE
      WRITE(2,112)(TEMP(I),I=1,NDATA)
  112 FORMAT(8F10.2)
      ENDFILE2
      REWIND2
      WRITE(NO,115)(TEMP(I),I=1,NDATA)
  115 FORMAT(10(3X,F10.2))
      STOP
      END
      SUBROUTINE LINREG
C
C     DIMENSION X(M,N),Y(M),A(N2),B(N),XBAR(N),YHAT(M),AA(N,N)
      DIMENSION A(144),AA(12,12),XBAR(12)
      COMMON/GFUNC/X(574,12),Y(574) ,YHAT(574),NDATA,B(12),AZERO,NA,NN,
     1 R2,NYEAR,YMEAN(52),YSTDV(52)
C
      M=NDATA    $    N=NA    $    N2=NN
```

```
C
C     CALCULATE AVERAGE X AND Y VALUES
C
      DO 200 I=1,N
      SUMX=0.0
      DO 100 J=1,M
  100 SUMX=SUMX+X(J,I)
  200 XBAR(I)=SUMX/FLOAT(M)
      SUMY=0.0
      DO 300 K=1,M
  300 SUMY=SUMY+Y(K)
      YBAR=SUMY/FLOAT(M)
C
C
C     CALCULATE REGRESSION MATRICES
C
      KK=1
      DO 500 I=1,N
      DO 500 J=1,N
      SUMA=0.0
      SUMB=0.0
      DO 400 K=1,M
      SUMA=SUMA+(X(K,I)-XBAR(I))*(X(K,J)-XBAR(J))
  400 SUMB=SUMB+(Y(K)-YBAR)*(X(K,I)-XBAR(I))
      AA(I,J)=SUMA
      A(KK)=SUMA
      KK=KK+1
  500 B(I)=SUMB
C
C
C     SOLVE REGRESSION MATRICES FOR COEFFICIENTS
C
      CALL SIMG(A,B,N,KS,N2)
      SUMX=0.0
      DO 600 I=1,N
  600 SUMX=SUMX+B(I)*XBAR(I)
      AZERO=YBAR-SUMX
C
      WRITE(6,008)
  008 FORMAT(///,10X,*VALUES OF THE CORRESPONDING REGRESSION COEFFICIENT
     1S*)
      WRITE(6,009)   (JJ,B(JJ),JJ=1,N)
  009 FORMAT(/,2(2X,5HAHAT(,I2,4H) = ,1PE16.8,8X))
      WRITE(6,010)   AZERO
  010 FORMAT(/,2X,8HAZERO = ,1PE16.8)
C
      DO 800 J=1,M
      SUMS1=0.0
      DO 700 K=1,N
  700 SUMS1=SUMS1+B(K)*X(J,K)
  800 YHAT(J)=AZERO+SUMS1
      CALL DCORL(Y,YHAT,M,R2)
C
      WRITE(6,013) R2
  013 FORMAT(//,2X,*R2 =*,1PE16.8)
C
      RETURN
      END
      SUBROUTINE SIMG(A,B,N,KS,NS)
C
      DIMENSION A(NS),B(N)
C
C     FORWARD SOLUTION
C
      TOL=0.0
      KS=0
      JJ=-N
      DO 65 J=1,N
      JY=J+1
      JJ=JJ+N+1
      BIGA=0
      IT=JJ-J
      DO 30 I=J,N
```

```
C
C     SEARCH FOR MAXIMUM COEFFICIENT IN COLUMN
C
      IJ=IT+I
      IF(ABS(BIGA)-ABS(A(IJ))) 20,30,30
   20 BIGA=A(IJ)
      IMAX=I
   30 CONTINUE
C
C     TEST FOR PIVOT LESS THAN TOLERANCE (SINGULAR MATRIX)
C
      IF(ABS(BIGA)-TOL) 35,35,40
   35 KS=1
      RETURN
C
C     INTERCHANGE ROWS IF NECESSARY
C
   40 I1=J+N*(J-2)
      IT=IMAX-J
      DO 50 K=J,N
      I1=I1+N
      I2=I1+IT
      SAVE=A(I1)
      A(I1)=A(I2)
      A(I2)=SAVE
C
C     DIVIDE EQUATION BY LEADING COEFFICIENT
C
   50 A(I1)=A(I1)/BIGA
      SAVE=B(IMAX)
      B(IMAX)=B(J)
      B(J)=SAVE/BIGA
C
C     ELEMINATE NEXT VARIABLE
C
      IF(J-N) 55,70,55
   55 IQS=N*(J-1)
      DO 65 IX=JY,N
      IXJ=IQS+IX
      IT=J-IX
      DO 60 JX=JY,N
      IXJX=N*(JX-1)+IX
      JJX=IXJX+IT
   60 A(IXJX)=A(IXJX)-(A(IXJ)*A(JJX))
   65 B(IX)=B(IX)-(B(J)*A(IXJ))
C
C     BACK SOLUTION
C
   70 NY=N-1
      IT=N*N
      DO 80 J=1,NY
      IA=IT-J
      IB=N-J
      IC=N
      DO 80 K=1,J
      B(IB)=B(IB)-A(IA)*B(IC)
      IA=IA-N
   80 IC=IC-1
C
      RETURN
      END
      SUBROUTINE DCORL(YO,YC,NPTS,RO)
C
      DIMENSION YO(NPTS),YC(NPTS)
C
      SUM1=0.
      SUM2=0.
      SUM3=0.
      SUMQ1=SUMQ2=0.
      DO 10 I=1,NPTS
      SUM1=SUM1+YO(I)
      SUM2=SUM2+YC(I)
```

```
      SUM3=SUM3+YO(I)*YC(I)
      SUMQ1=SUMQ1+YO(I)*YO(I)
      SUMQ2=SUMQ2+YC(I)*YC(I)
   10 CONTINUE
      DATA=FLOAT(NPTS)
      FNUM=ABS(DATA*SUM3-SUM1*SUM2)
      DNOM=SQRT(DATA*SUMQ1-SUM1*SUM1)*SQRT(DATA*SUMQ2-SUM2*SUM2)
      RO=FNUM/DNOM
      RETURN
      END
      SUBROUTINE AUTOKAL(NSET,NLAG,NO,ERRAVG,ERRSTDV)
C
C        NSET = NUMBER OF INPUT DATA SETS, MAX = 5
C        NLAG = TIME-LAG, MAX = 5
C
      DIMENSION S(3)
      COMMON/WORK/C1(574),C2(574),TEMP(2609)
      COMMON/GFUNC/X(574,12),Y(574)  ,YHAT(574),NDATA,B(12),AZERO,NA,NN,
     1 R2,NYEAR,YMEAN(52),YSTDV(52)
      COMMON/FILTER/H(3),GAIN(3),P(3,3),Q(3,3),R,U,V
C
C  ---  INITIALIZATION  ---
      ALPHA=.5
      NN=NSET*NLAG
      NN1=NN
      NLP1=NLAG+1
      NLM1=NLAG-1
      U=V=0.
      DO 10 I=1,3
      S(I)=.5
      H(I)=0.
      GAIN(I)=0.
      DO 10 J=1,3
      P(I,J)=0.
   10 Q(I,J)=0.
      DO 14 I=1,NN1
      Q(I,I)=.1
   14 P(I,I)=400.
      R=.0001
      ITER=0
C  ---  FORM THE OBSERVATION MATRIX H  ---
      CALL HFORM(ITER,NLAG,H)
C  ---  START ITERATION  ---
      SUM1=SUM2=0.
      DO 30 I=1,NLAG
      C1(I)=C2(I)=.5
   30 CONTINUE
  100 ITER=ITER+1
      YO=Y(ITER)
      CALL KALSOL(NO,NN1,ALPHA,YO,ITER,ERR,S)
      C1(ITER)=S(1)   $   C2(ITER)=S(2)
      SUM1=SUM1+ERR
      SUM2=SUM2+ERR*ERR
C  ---  CHECK TO STOP  ---
      IF(ITER.EQ.NDATA) GO TO 120
C  ---  UPDATE THE OBSERVATION MATRIX H  ---
      DO 38 J=1,NLM1
      IRANK=NLAG-J
      IRP1=IRANK+1
   38 H(IRP1)=H(IRANK)
      H(1)=YO
      GO TO 100
  120 CONTINUE
      FN=FLOAT(NDATA)   $   FN1=FN-1.
      ERRAVG=SUM1/FN
      SUM2=SUM2/FN
      ERRSTDV=SQRT((SUM2-ERRAVG*ERRAVG)*(FN/FN1))
      WRITE(NO,150) ERRAVG,ERRSTDV
  150 FORMAT(/,5X,*ERRAVG = *,F10.5,10X,*ERRSTDV = *,F10.5)
      RETURN
      END
      SUBROUTINE HFORM(ITER,NLAG,H)
```

```
C
C   ---  FORM THE H ARRAY  ---
C
      DIMENSION H(3)
      COMMON/GFUNC/X(574,12),Y(574)  ,YHAT(574),NDATA,B(12),AZERO,NA,NN,
     1 R2,NYEAR,YMEAN(52),YSTDV(52)
C
      DO 10 I=1,NLAG
      ITER=ITER+1
      IH=NLAG-I+1
      H(IH)=Y(ITER)
   10 CONTINUE
      RETURN
      END
      SUBROUTINE KALSOL(NO,NN,ALPHA,YO,ITER,ERR,X)
C
      DIMENSION X(3),PHT(3)
      COMMON/FILTER/H(3),GAIN(3),P(3,3),Q(3,3),R,U,V
C
      IQUP=0
      EPS=.000001
C   ---  COMPUTE KALMAN GAIN  ---
      DO 20 I=1,NN
      PHT(I)=0.
      DO 20 J=1,NN
   20 PHT(I)=PHT(I)+P(I,J)*H(J)
      HPHT=0.
      DO 22 I=1,NN
   22 HPHT=HPHT+H(I)*PHT(I)
      DNOM=R+HPHT
      HX=0.
      DO 26 I=1,NN
   26 HX=HX+H(I)*X(I)
      DEL=YO-HX
      CALL PQVAR(ITER,DNOM,DEL,U,V)
      TEST=9.*V*DNOM
      IF(DEL.GT.TEST) GO TO 10
      DO 24 I=1,NN
   24 GAIN(I)=PHT(I)/DNOM
      GO TO 15
   10 DO 12 I=1,NN
   12 GAIN(I)=0.
C   ---  CALCULATE THE BEST ESTIMATE FOR X  ---
   15 DO 28 I=1,NN
   28 X(I)=X(I)+GAIN(I)*DEL
C   ---  UPDATE THE ERROR-COVARIANCE MATRIX P  ---
      IF(IQUP.EQ.0) GO TO 27
      CALL QUPDAT(NN,PHT,ALPHA)
   27 DO 30 I=1,NN
      DO 30 J=1,NN
   30 P(I,J)=P(I,J)+Q(I,J)-GAIN(I)*GAIN(J)*DNOM
      DO 31 I=1,NN
      DO 31 J=1,NN
      IF(I.EQ.J) GO TO 29
      P(I,J)=0.
      GO TO 31
   29 IF(P(I,J).LE.EPS) P(I,J)=EPS
   31 CONTINUE
      YEST=0.
      DO 34 I=1,NN
   34 YEST=YEST+H(I)*X(I)
      ERR=YO-YEST
      RETURN
      END
      SUBROUTINE PQVAR(ITER,DNOM,DEL,U,V)
      U=U+(1./FLOAT(ITER))*(ALOG(DNOM)-U)
      V=V+(1./FLOAT(ITER))*((DEL*DEL/DNOM)-V)
      IF(V.LT..000001) V=.000001
      OBJ=-U-ALOG(V)
      RETURN
      END
      SUBROUTINE QUPDAT(NN,PHT,ALPHA)
      DIMENSION A(3,3),PHT(3)
```

```
      COMMON/FILTER/H(3),GAIN(3),P(3,3),Q(3,3),R,U,V
      DO 10 I=1,NN
      DO 10 J=1,NN
   10 A(I,J)=0.
      DO 20 I=1,NN
      DO 20 J=1,NN
   20 A(I,J)=GAIN(I)*PHT(J)
      COEF=(1./ALPHA)-1.
      DO 30 I=1,NN
      DO 30 J=1,NN
   30 Q(I,J)=COEF*(P(I,J)-A(I,J))
      RETURN
      END
      SUBROUTINE DSTAT(NDATA,Y,RMEAN,RSTDV,RLAG1)
      DIMENSION Y(NDATA)
      RSUM=RSSQ=0.
      RLAG1=0.
      ND1=NDATA-1
      DO 68 I=1,ND1
      IP1=I+1
   68 RLAG1=RLAG1+Y(I)*Y(IP1)
      DO 70 I=1,NDATA
      RSUM=RSUM+Y(I)
   70 RSSQ=RSSQ+Y(I)*Y(I)
      FD=FLOAT(NDATA)    $    FD1=FD-1.
      RLAG1=RLAG1/RSSQ
      RMEAN=RSUM/FD
      RSSQ=RSSQ/FD
      RSTDV=SQRT((RSSQ-RMEAN*RMEAN)*(FD/FD1))
      RETURN
      END
      SUBROUTINE HARMON(W,FI,C,FY)
      DIMENSION C(13)
      X1=COS(W)    $    X2=SIN(W)    $    X3=COS(2.*W)    $    X4=SIN(2.*W)
      X5=COS(3.*W)    $    X6=SIN(3.*W)    $    X7=COS(4.*W)    $ X8=SIN(4.*W)
      X9=COS(5.*W)   $   X10=SIN(5.*W)   $   X11=COS(6.*W)   $   X12=SIN(6.*W)
      FY=C(1)*X1+C(2)*X2+C(3)*X3+C(4)*X4+C(5)*X5+C(6)*X6+C(7)*X7+
     1 C(8)*X8+C(9)*X9+C(10)*X10+C(11)*X11+C(12)*X12+C(13)
      RETURN
      END
      SUBROUTINE MINMAX(QMIN,QMAX)
      COMMON/GFUNC/X(574,12),Y(574)  ,YHAT(574),NDATA,B(12),AZERO,NA,NN,
     1 H2,NYEAR,YMEAN(52),YSTDV(52)
      QMIN=100.    $    QMAX=0.
      DO 140 I=1,NDATA
      IF(Y(I).GT.QMAX) QMAX=Y(I)
      IF(Y(I).LT.QMIN) QMIN=Y(I)
  140 CONTINUE
      RETURN
      END
      SUBROUTINE TREND
      COMMON/GFUNC/X(574,12),Y(574),YHAT(574),NDATA,B(12),AZERO,NA,NN,
     1 H2,NYEAR,YMEAN(52),YSTDV(52)
      FN=11.    $    FN1=10.
      DO 20 I=1,52
      SUM=SSQ=0.
      DO 10 J=1,NYEAR
      JM1=J-1'
      K=I+52*JM1
      SUM=SUM+Y(K)
   10 SSQ=SSQ+Y(K)*Y(K)
      YMEAN(I)=SUM/FN
      SSQ=SSQ/FN
      YSTDV(I)=SQRT((SSQ-YMEAN(I)*YMEAN(I))*(FN/FN1))
   20 CONTINUE
      N=0
      DO 30 J=1,NYEAR
      DO 30 I=1,52
      N=N+1
      Y(N)=(Y(N)-YMEAN(I))/YSTDV(I)
   30 CONTINUE
      Y(573)=(Y(573)-YMEAN(1))/YSTDV(1)
      Y(574)=(Y(574)-YMEAN(2))/YSTDV(2)
      RETURN
      END
```

Program for Computing Weekly Discharge Non-Point Sources

```
      PROGRAM LOSSL(INPUT,OUTPUT,TAPE1,TAPE7)
C
C      THIS PROGRAM FINDS THE DIFFERENCE BETWEEN A DOWNSTREAM OUTFLOW
C      AND UP TO SIX UPSTREAM INFLOWS TO CALCULATE NONPOINT SOURCES
C      OF INFLOW OR OUTFLOW
C
      DIMENSION INFL(6,2620),OUTFL(2620),NPS(2609)
      REAL INFL,NPS
C
C      NI=NUMBER OF INFLOWS              NT=NUMBER OF DISCHARGE VALUES
C
      READ 5,NI,NT,NAME
C
C      DISCHARGE VALUES ARE READ FROM TAPE1 WITH OUTFLOW FIRST
C
      READ(1,20) (OUTFL(I),I=1,2620)
      IF(EOF(1)) 6,100
    6 DO 15 I=1,NI
      READ(1,20)(INFL(I,J),J=1,2620)
      IF(EOF(1)) 15,120
   15 CONTINUE
   20 FORMAT(8F10.2)
      DO 25 J=1,NT
      SUMINF=0.0
      DO 30 I=1,NI
      SUMINF=SUMINF+INFL(I,J)
   30 CONTINUE
      NPS(J)=OUTFL(J)-SUMINF
   25 CONTINUE
C
C      OUTPUT IS ENCODED TO TAPE7
C
      WRITE(7,20) NPS
      PRINT 50,NAME,(NPS(I),I=2590,2609)
      SUM=0.0
      DO 40 I=1,NT
      SUM=SUM+NPS(I)
   40 CONTINUE
      NPSBAR=SUM/(FLOAT(NT))
      PRINT 55, NPSBAR
   55 FORMAT(/2X*AVERAGE GAIN-LOSS=* F12.2)
  100 PRINT 111
      GO TO 999
  120 PRINT112
  112 FORMAT(2X*INFLOW TOO BIG*)
  111 FORMAT(2X*CHECK OUT THE FILES TOO MUCH INFO OR YOU ARE DONE*)
    5 FORMAT(2I5,A9)
   50 FORMAT(///2X        *STATION=*A9/2X*NPS 2590-2609=*/(10F10.2))
  999 CONTINUE
      STOP
      END
```

APPENDIX E

Plots of Actual and Simulated
Weekly Discharge at Greenwood,
Swan Lake and Lambert

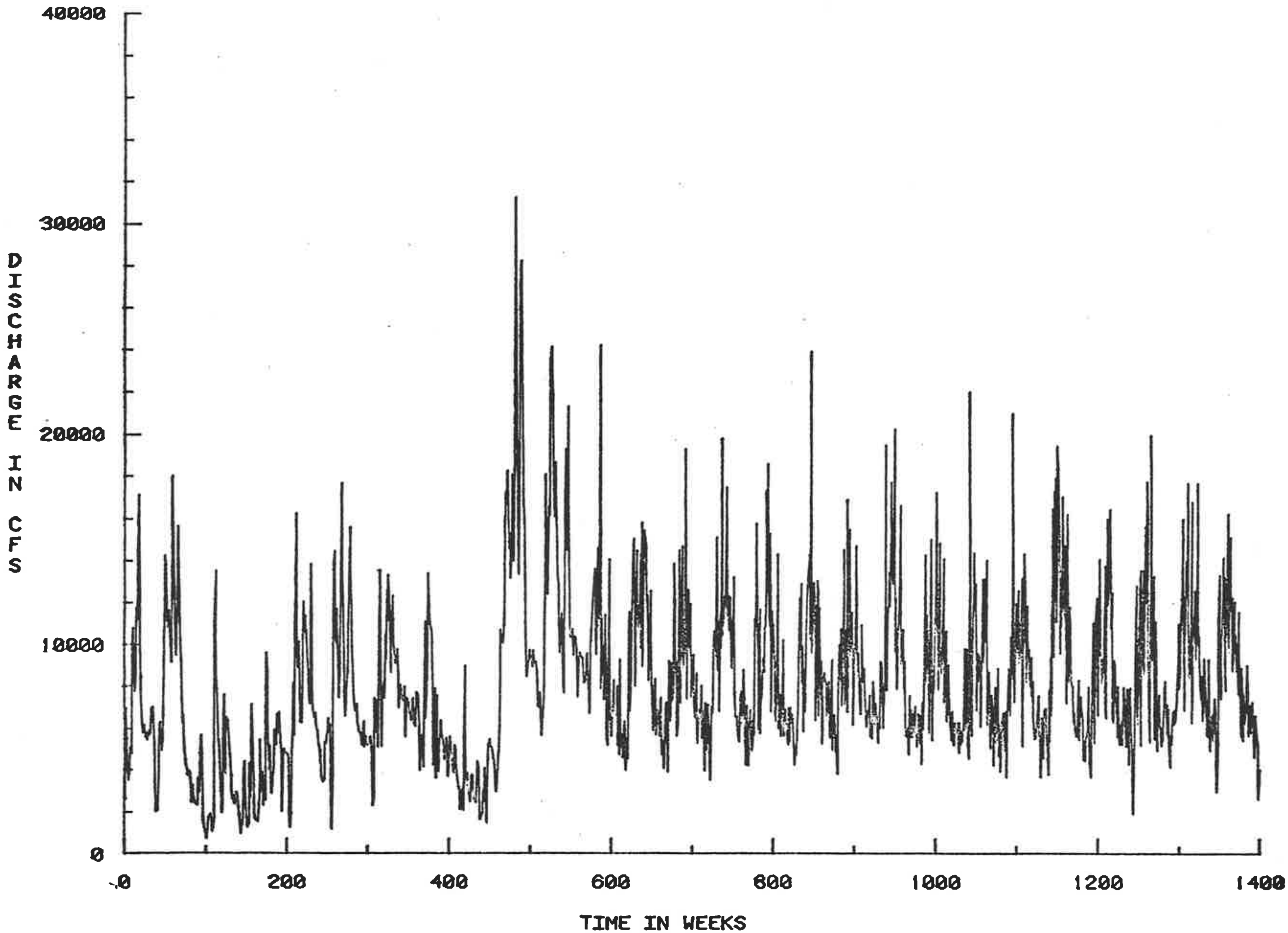


Figure E-1. 50-year weekly hydrograph at Greenwood.

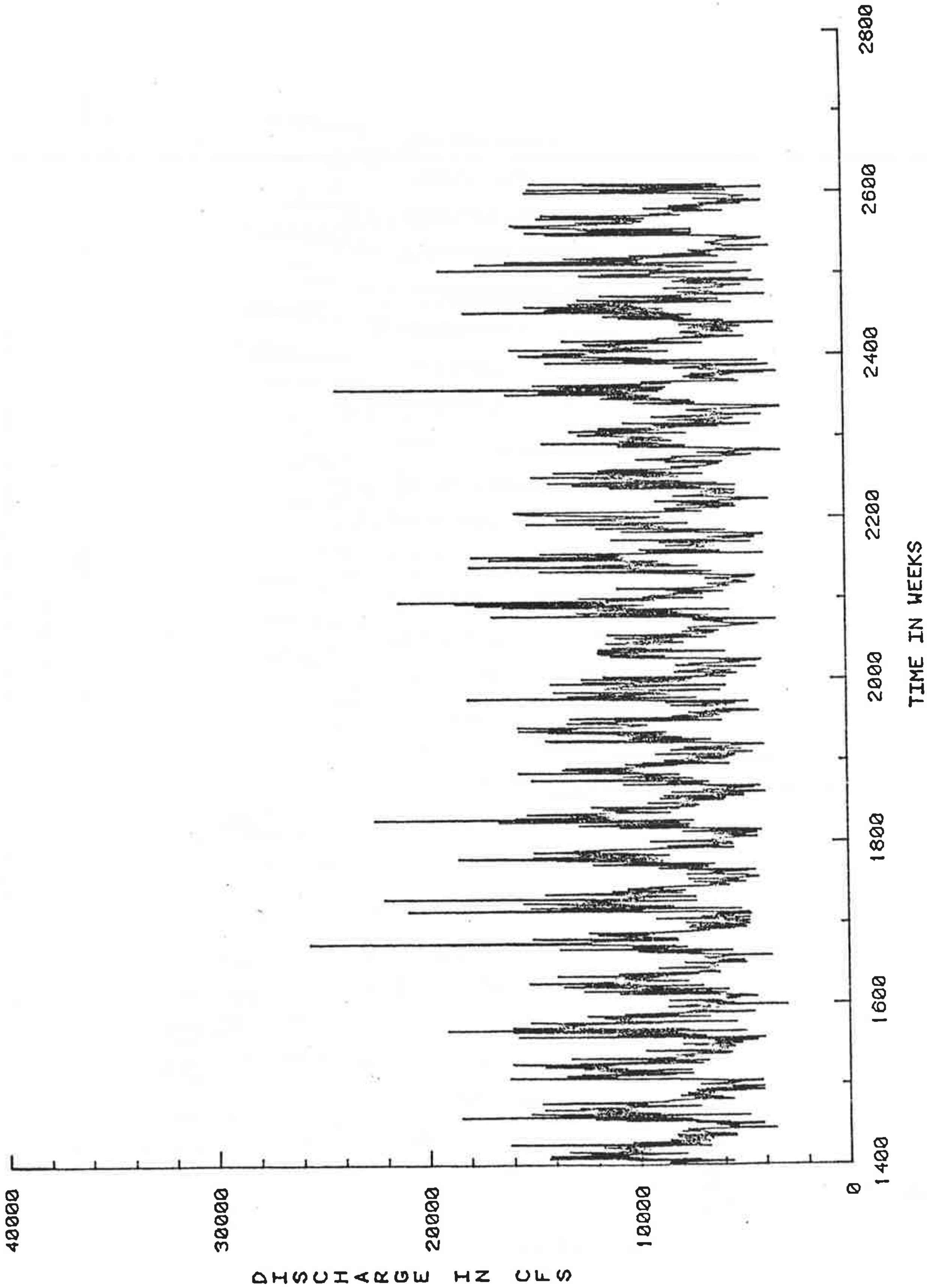


Figure E-1. (continued)

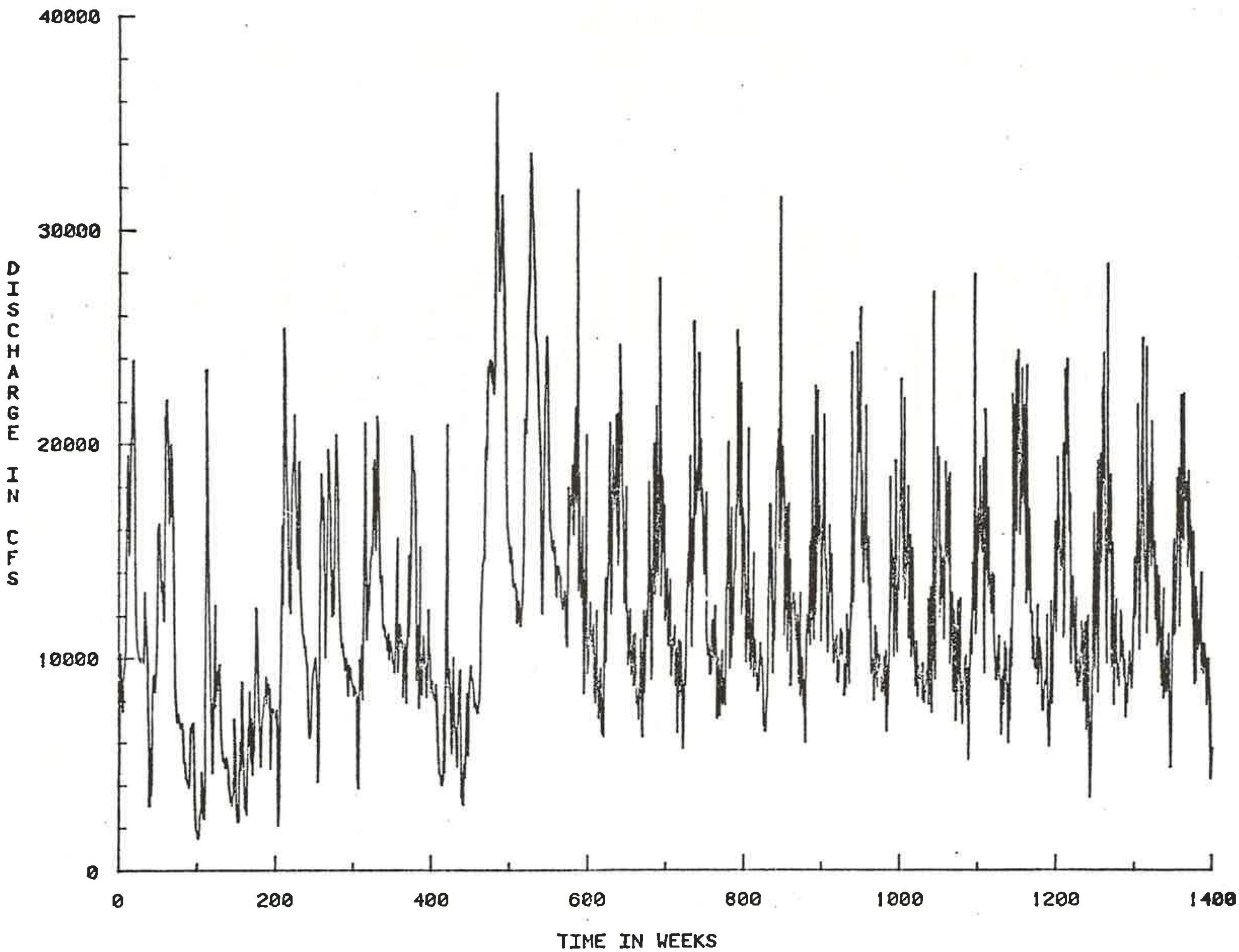


Figure E-2. 50-year weekly hydrograph at Swan Lake.

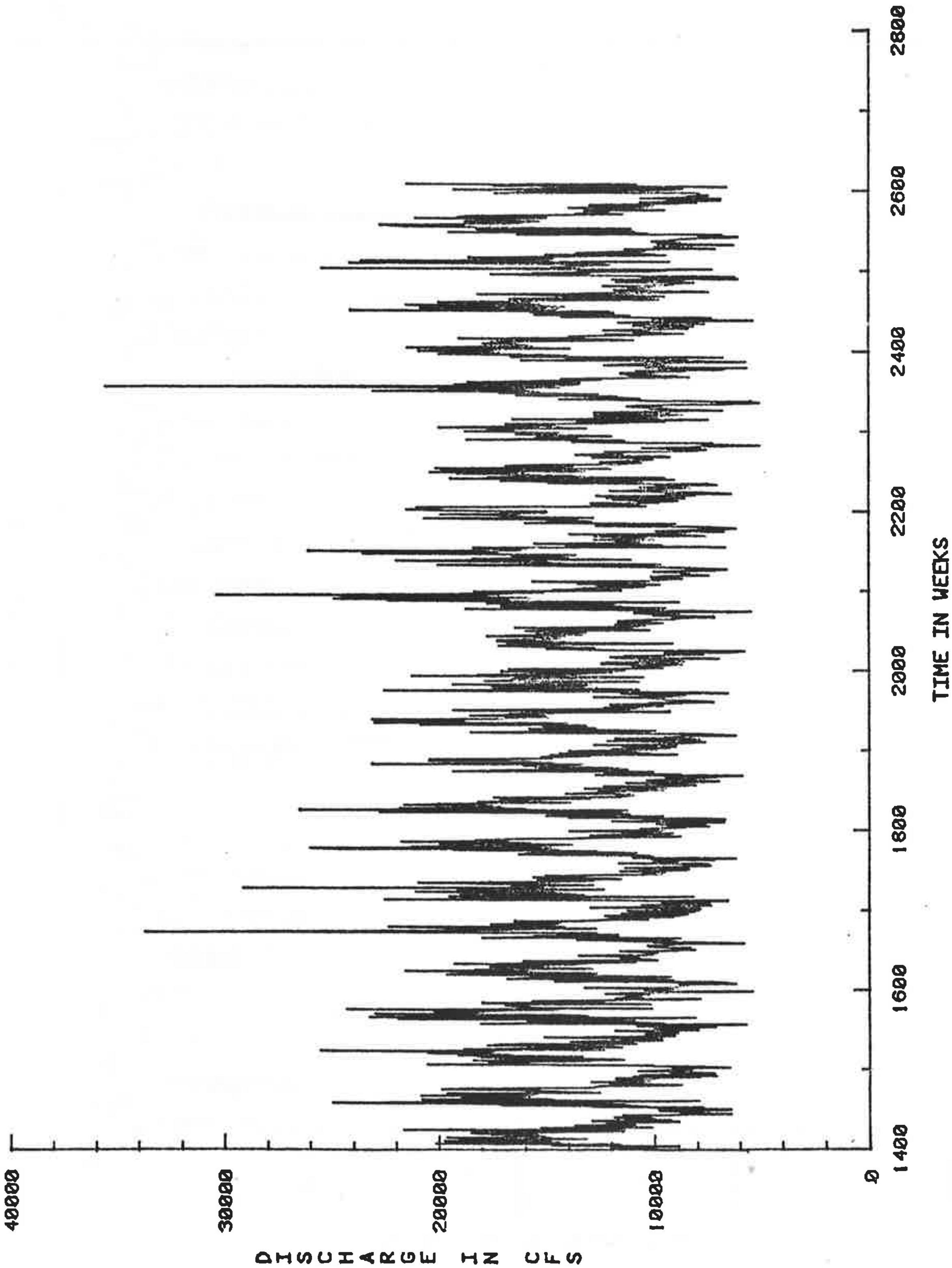


Figure E-2. (continued)

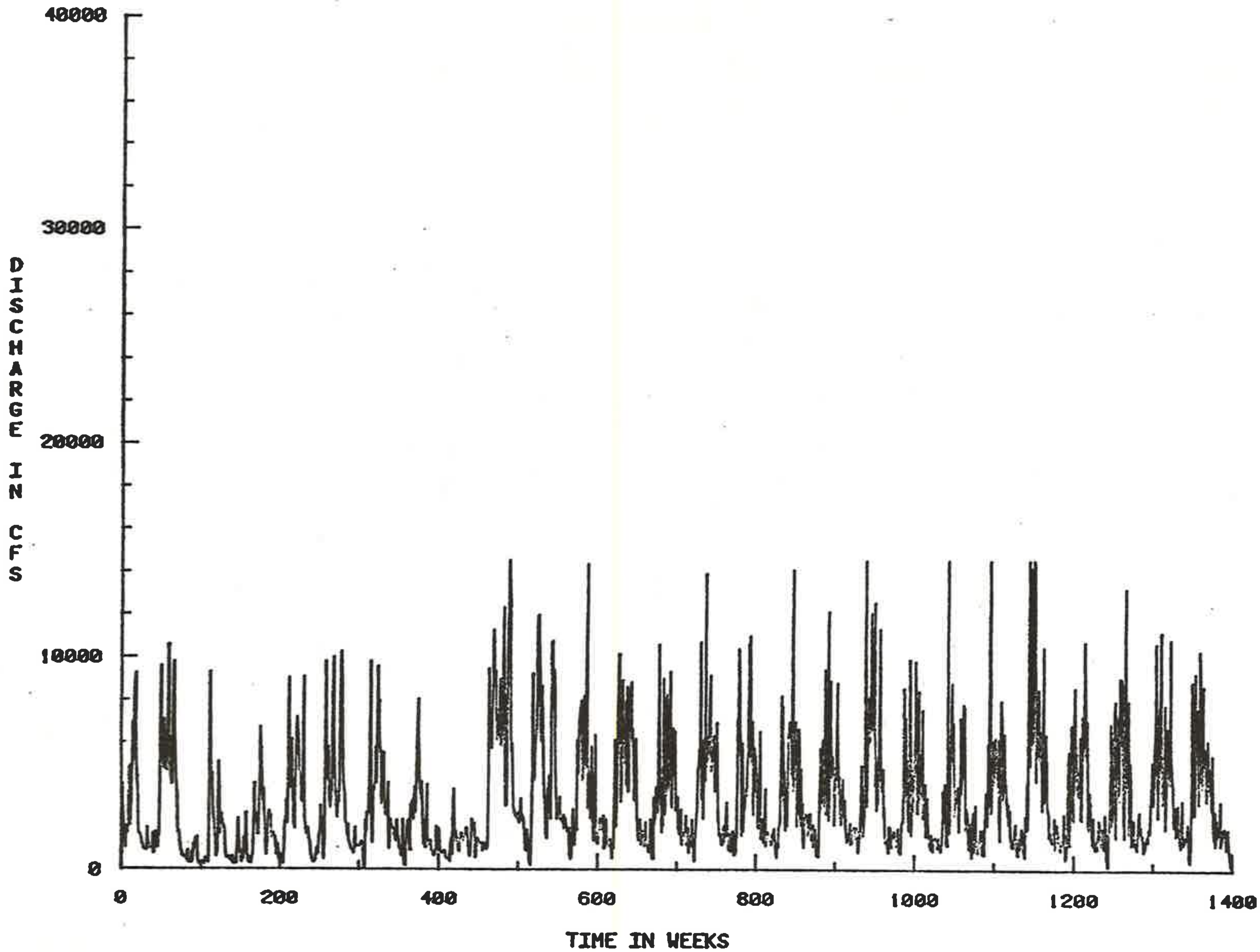


Figure E-3. 50-year weekly hydrograph at Lambert.

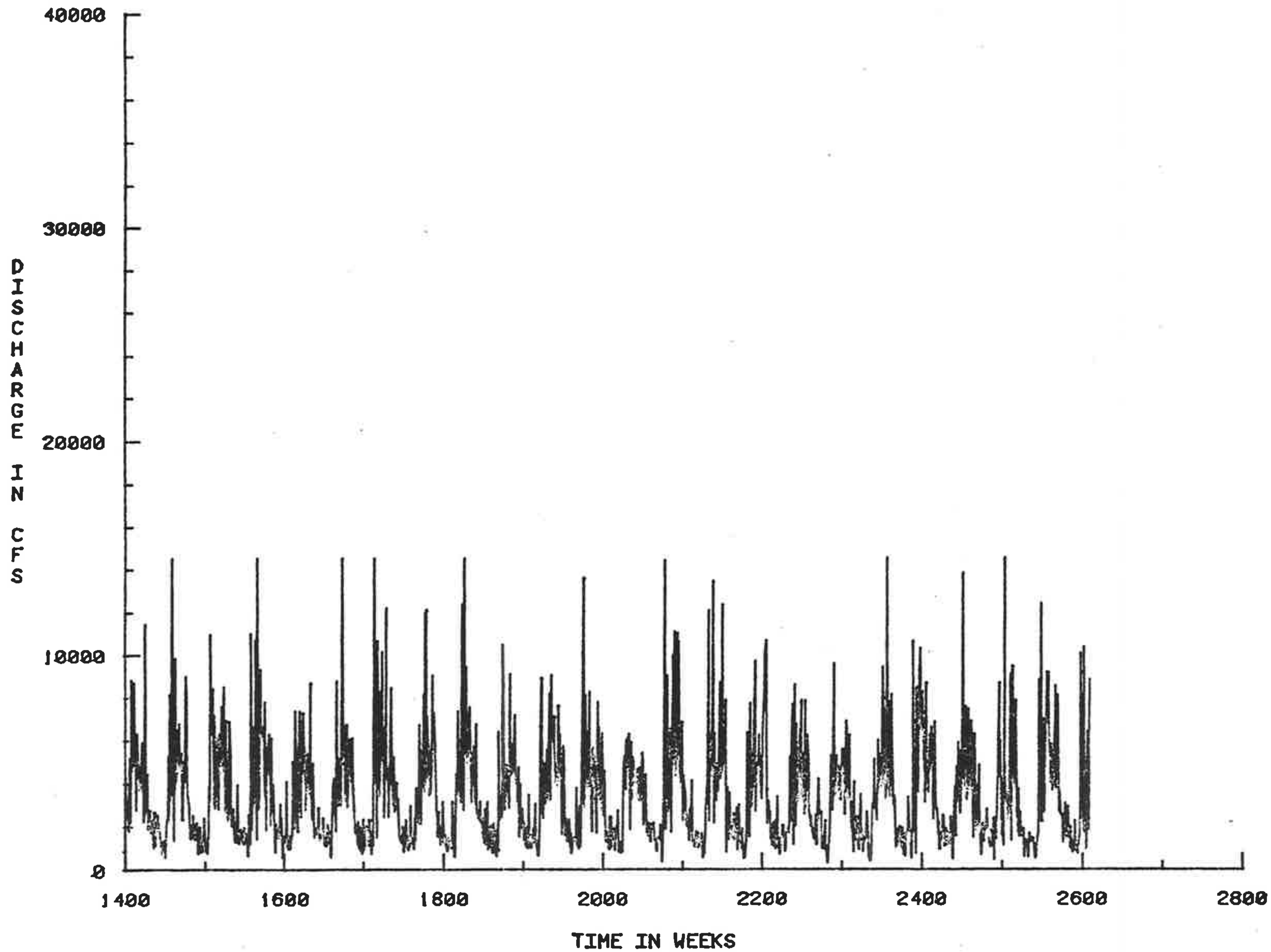


Figure E-3. (continued)